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Evaluation of Information Technology for „Industrie 4.0“ Production systems

Prof. Dr.-Ing. Michael Weyrich

25. Oktober 2016,
NOKIA-Lectures at University of Stuttgart

Project Team

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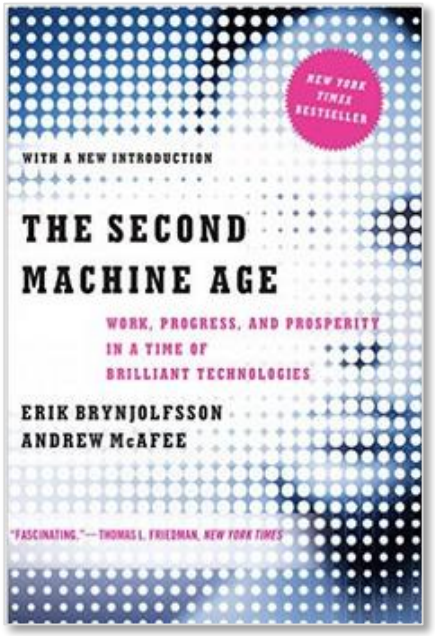
Agenda

- „Industrie 4.0“
- Expected Contribution of Information Technology
- On how to measure the Impact of IT
  - A Model of IT „Abilities“
  - Key Performance Indicators
  - Identification of Value Patterns
- Conclusion

High expectations in „Digitalisation“

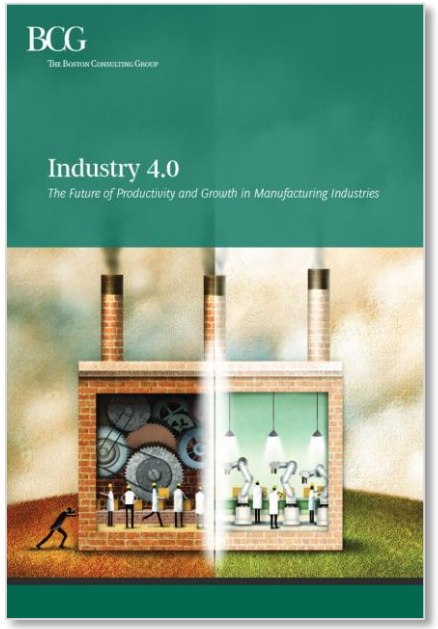
Considering the globalization trend, new work and production approaches need to be conceived to shape the inevitable change …

*2014: New York Times Bestseller “how **digital technology is transforming our work and our lives**”*



*2014: „**78 Billon Euro adding value till 2025**“*

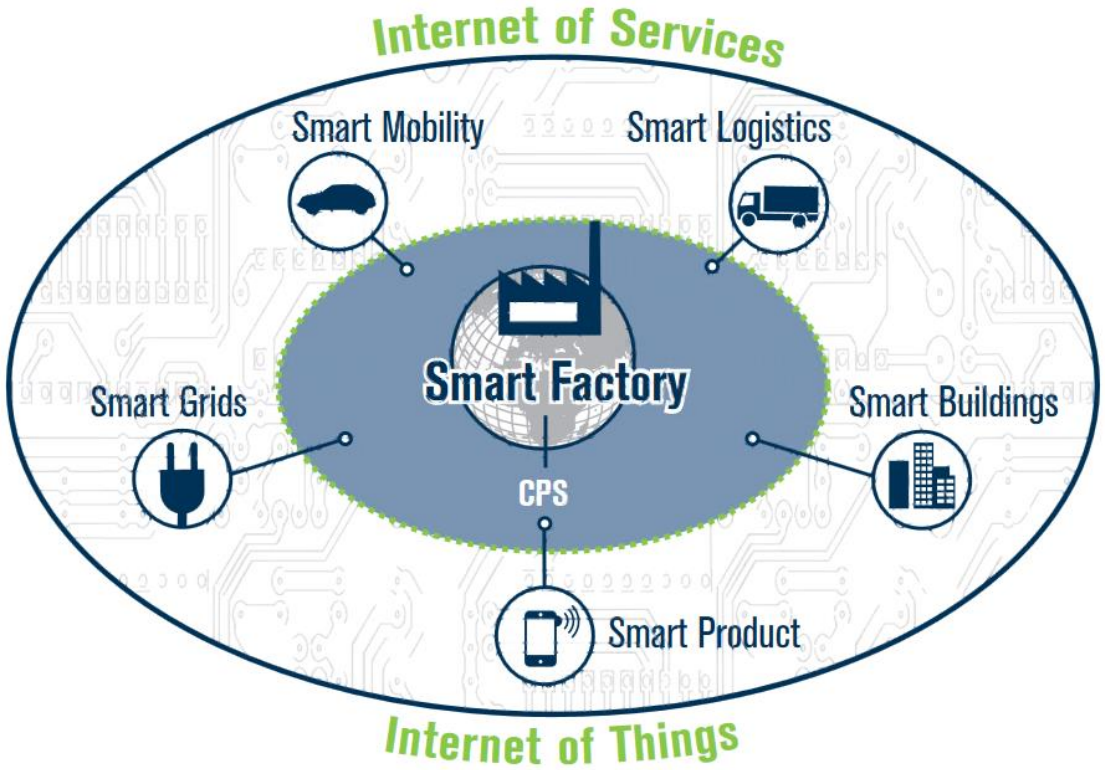
*2015: „**390.000 new jobs in Germany till 2025 “***



[4, 5]

Value-adds in Production are driven by IT

+++ fast launch of new products +++ fully utilize manufacturing equipment +++ manage peak loads +++ cover up supply chain issues +++ follow customer requests +++ adjust production +++ be efficient +++



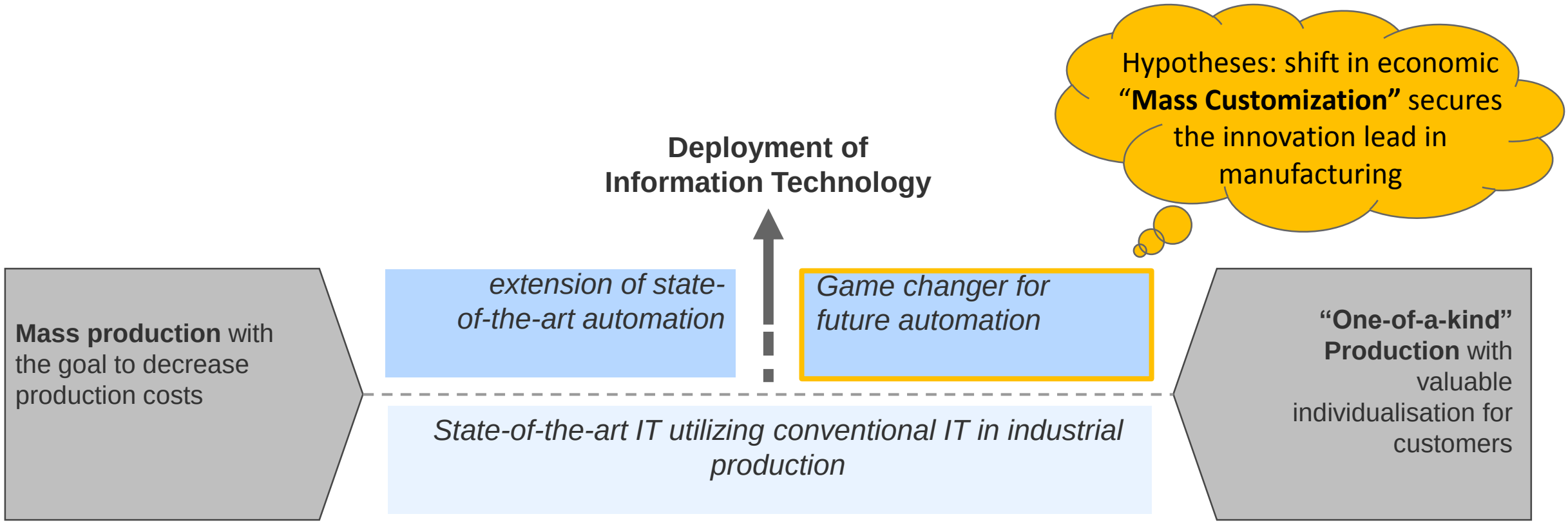
[3]

*"In the manufacturing environment, vertical networking, end-to-end engineering and horizontal integration … is set to usher in the fourth stage of industrialisation – **INDUSTRIE 4.0**".*

Acatech and Forschungsunion: Recommendation for implementing the strategic initative INDUSTRIE 4.0, April 2013

What difference can IT make in „Industrie 4.0“?

The scenario envisions a highly flexible mass production, which can produce even a one-of-a-kind type of products by means of automated manufacturing in a highly efficient way.

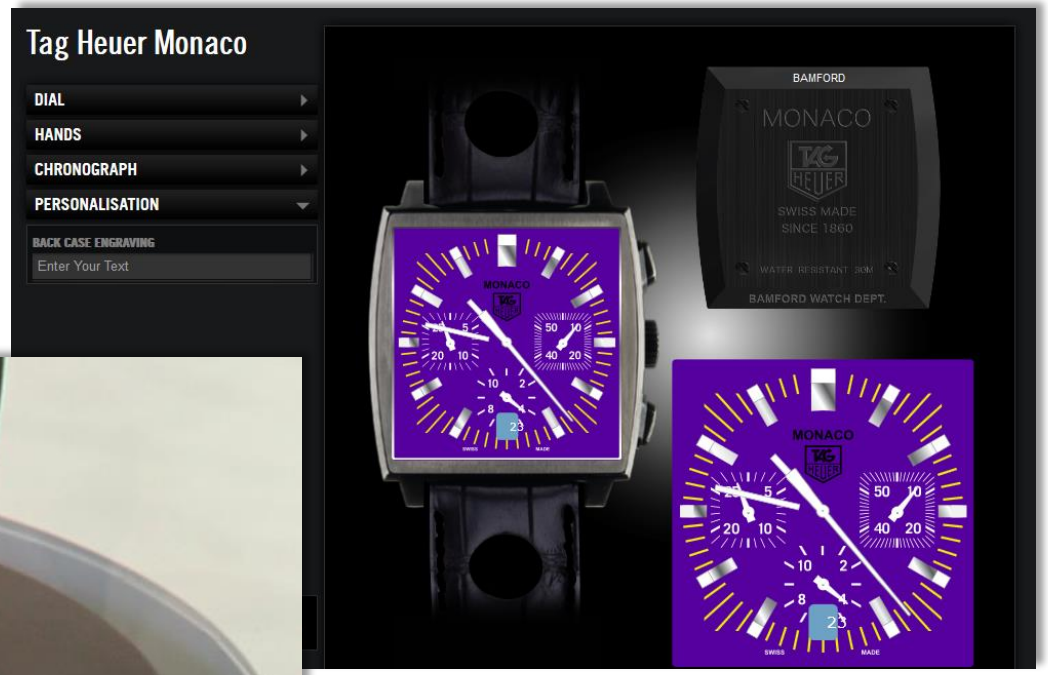


[1]

Mass Customisation

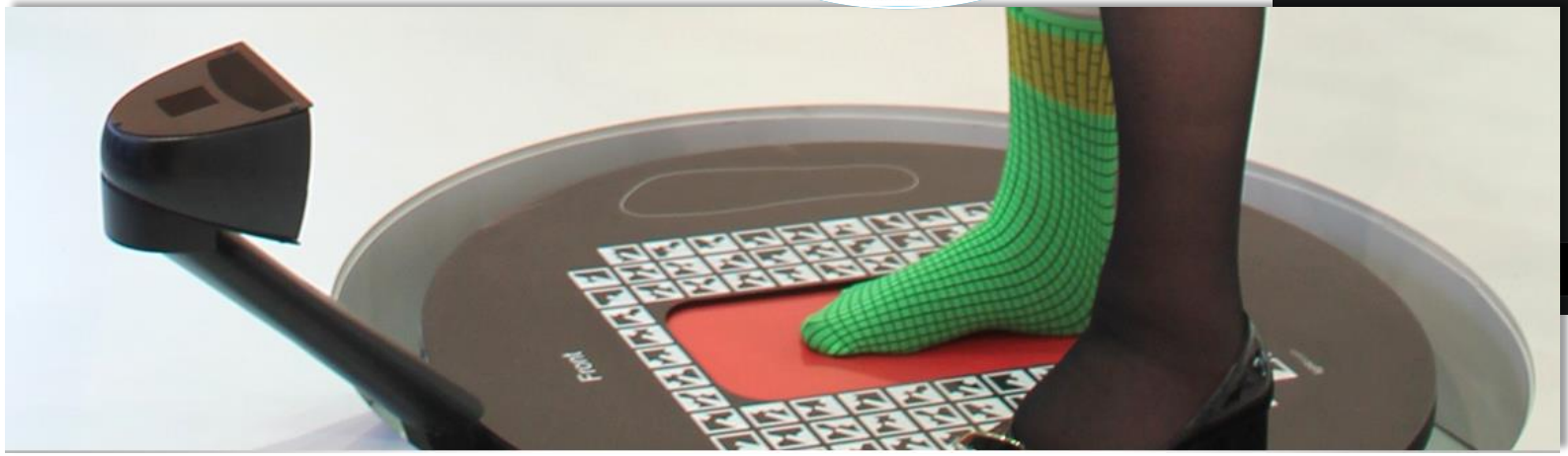
"… to offer products or services which meet the demands of each individual customer, but are produced by means of industrial mass manufacturing …"

Example: Individual Watches



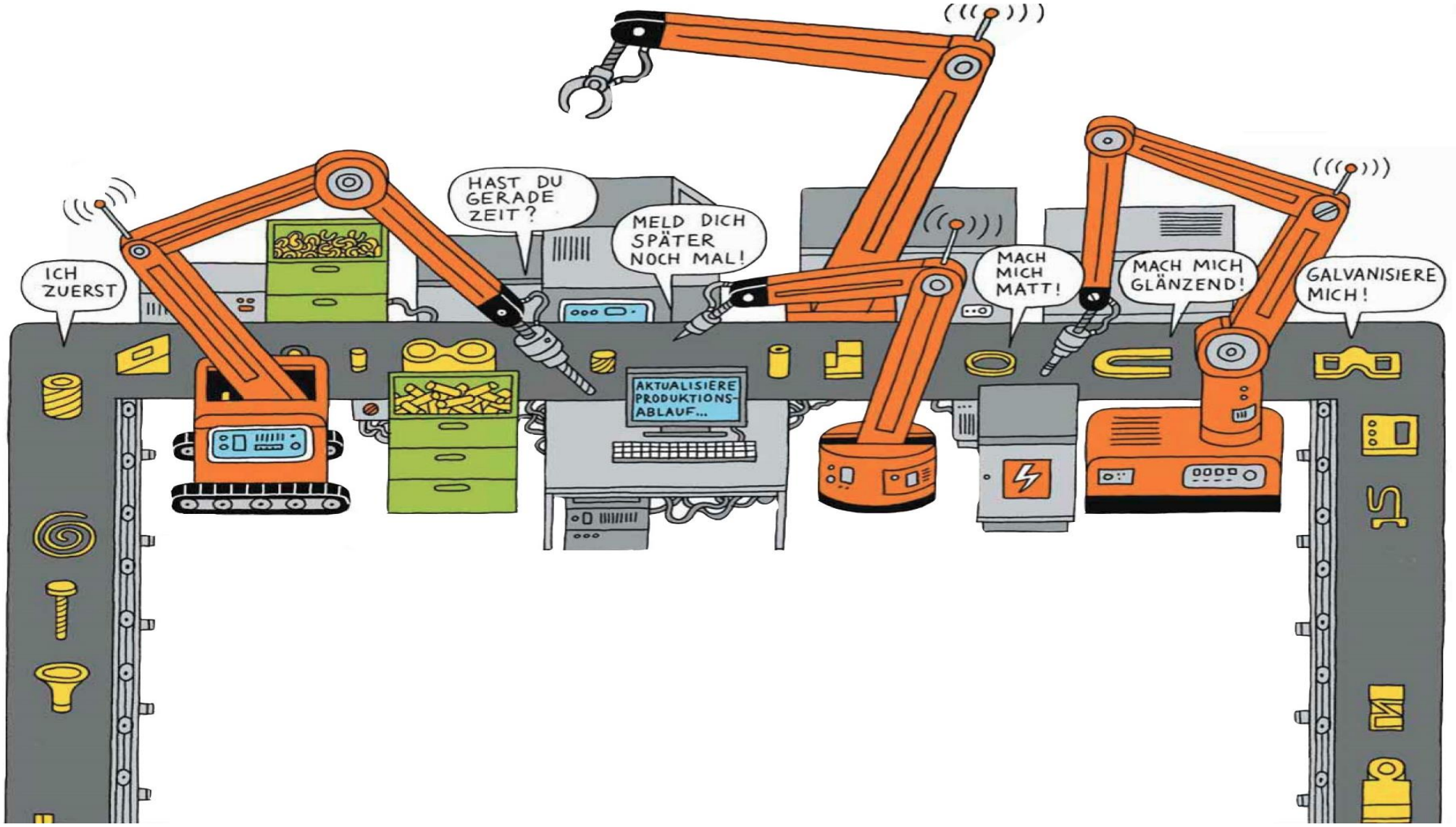
Source: http://customiser.bamfordwatchdepartment.com/customise_tag_monaco-REVISE.cfm

Example: Taylor made shoes



http://frankpiller.com/mass-customization/

Visualization of „DIE ZEIT“: “Cyber Physical Production” of the Future



Bildquelle: [Zeit2014/5]

Research ambitions and Value-add Claim of "Industrie 4.0"

IAS Analysis (2015): The Value-Adds are very generic and reflect the various research ambitions in manufacturing automation and IT of the past decades.

Research Ambitions

networked systems
services
decision support
ad-hoc rescheduling
wireless communication
artificial intelligence
reference architectures
adaptation
internet of things
reasoning
data processing
knowledge creation
real-time decision making
reconfiguration
self-x
Intelligent objects
autonomy
orchestration
distributed control
flattening of hierarchies
seamless integration
end-to-end process
networking technologies
optimisation

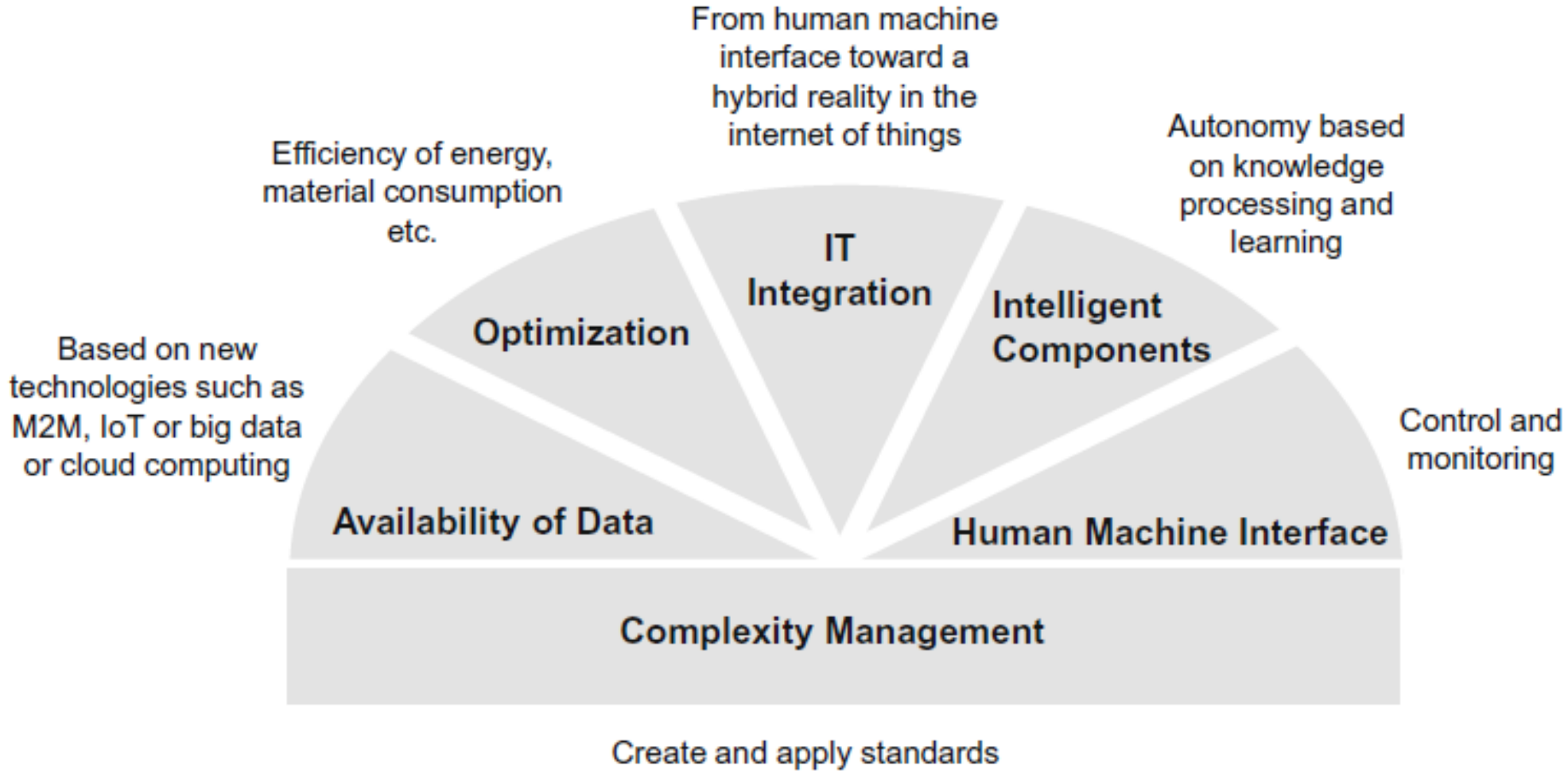
Value-add Claims

flexibility
changeability
individualized products
maintainability
smart factory
shorter configuration
efficient manufacturing
horizontal integration
vertical integration
efficiency
agility
lot size 1
new business models
Dynamic value networks

[1]

What makes the IT flavor of "Industrie 4.0" and "Cyber-physical Systems"?

From processing of distributes big data, Men-machine interaction, new control approaches to autonomous systems.

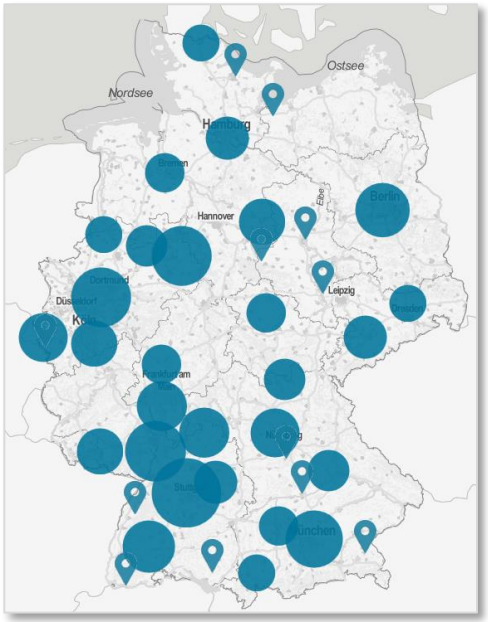


[1]

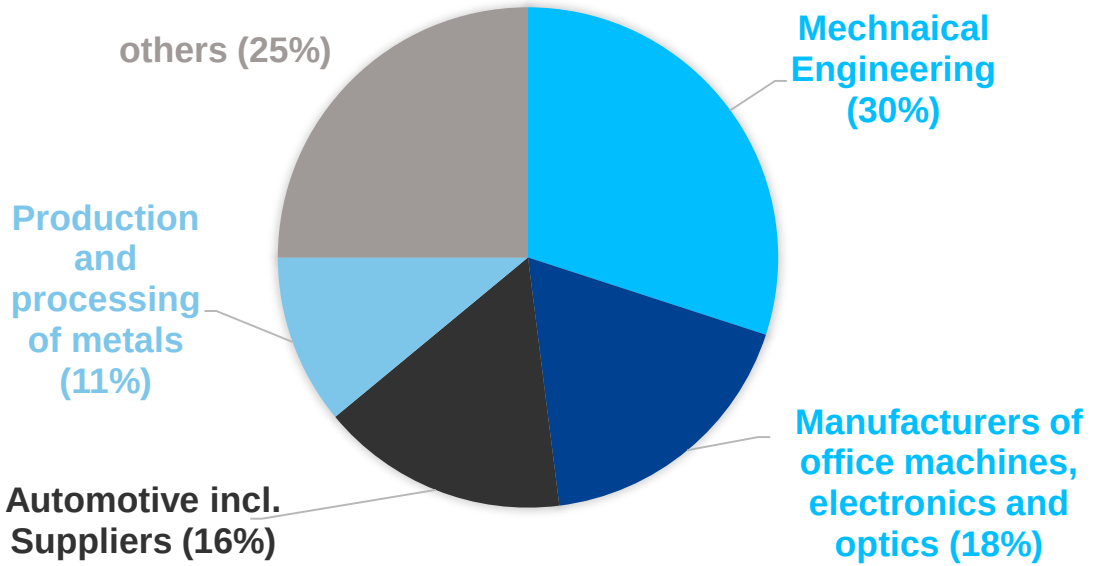
„Industrie 4.0“ Map of Germany

The map shows more than 250 (Oct. 2016) practical use-cases which are in an early stage of development

Locations



Use-Case Segments



Solution types

- **Mainly: “**Decision Support and Assistance systems” for automated manufacturing
- **Also:** „Solutions for Energy Efficiency“, „Predictive/ Preventive Maintenance“, „Changeable manufacturing systems“ and „Adaptive Logistics“

[6, 7]

How to measure and evaluate the value adds of “Industrie 4.0” Manufacturing and “Cyber Physical Production Systems”?

Quelle: Freepick.com

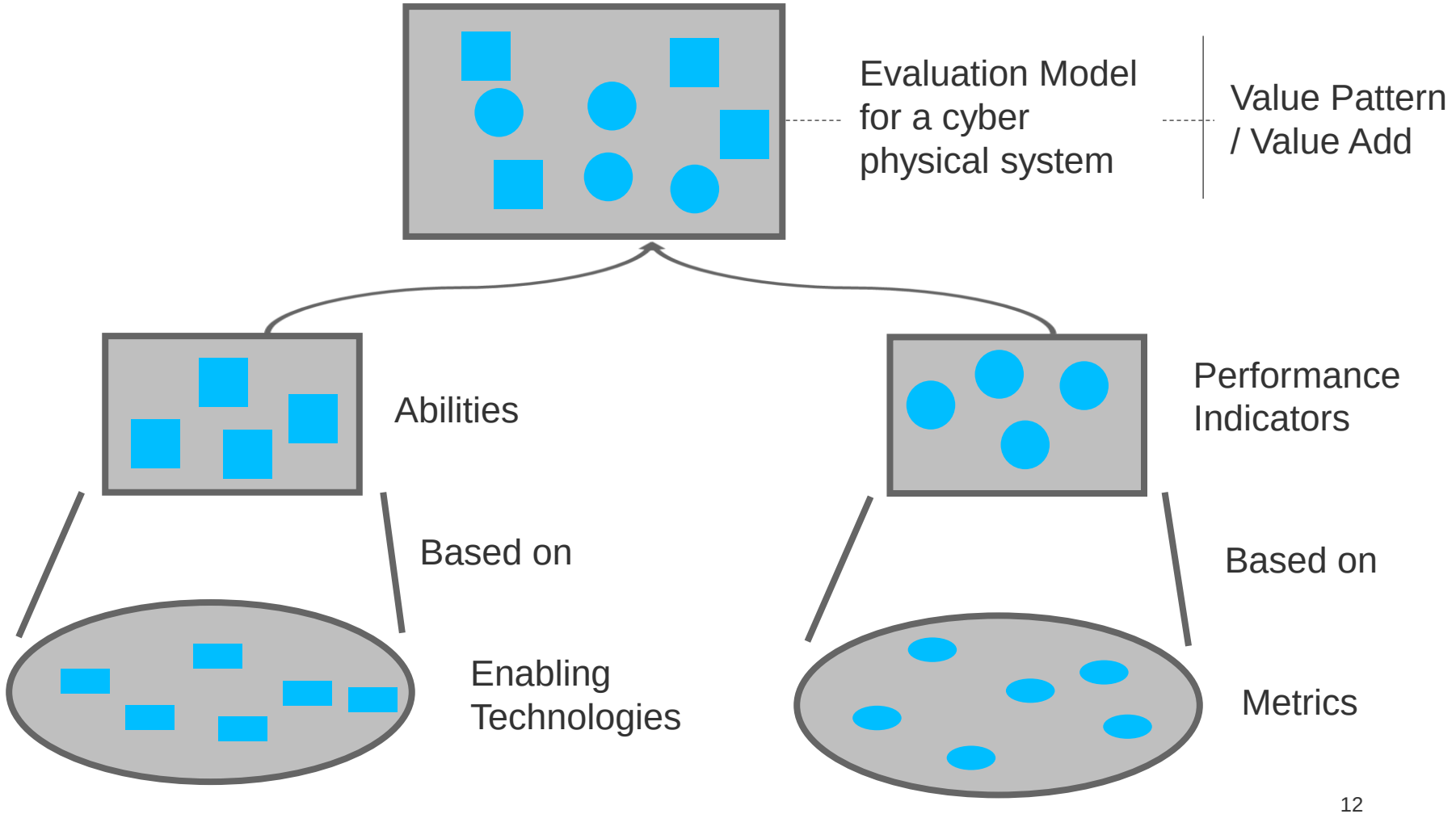
Foresight based on an “advanced scenario method”

Identifies IT Abilities and related Performance indicators which leads to value patterns. (Methodology: known from macroeconomics for trend analysis in economy [8])

Provides a framework for analysis, projection and simulation

Group discussions of experts

Literature surveys



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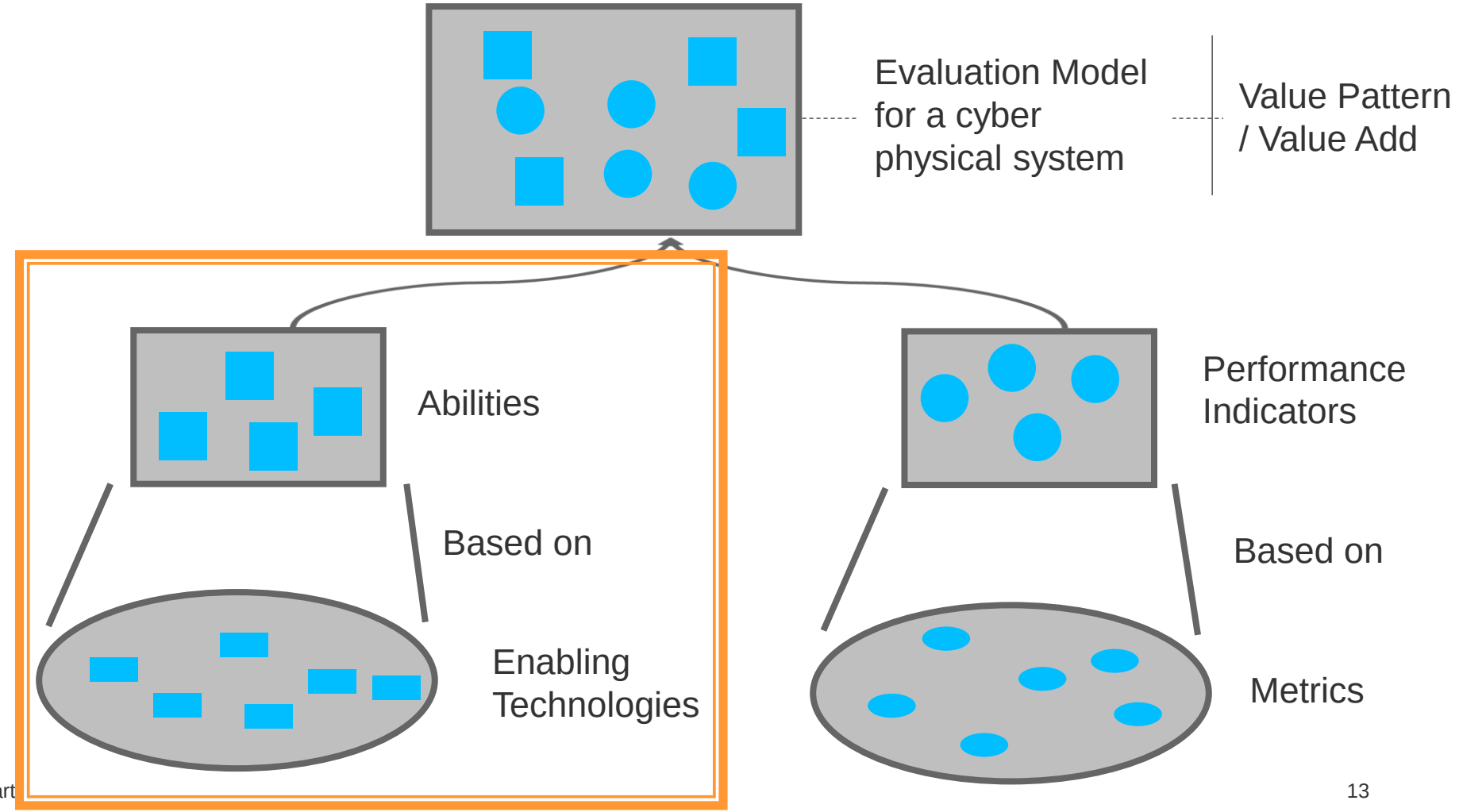
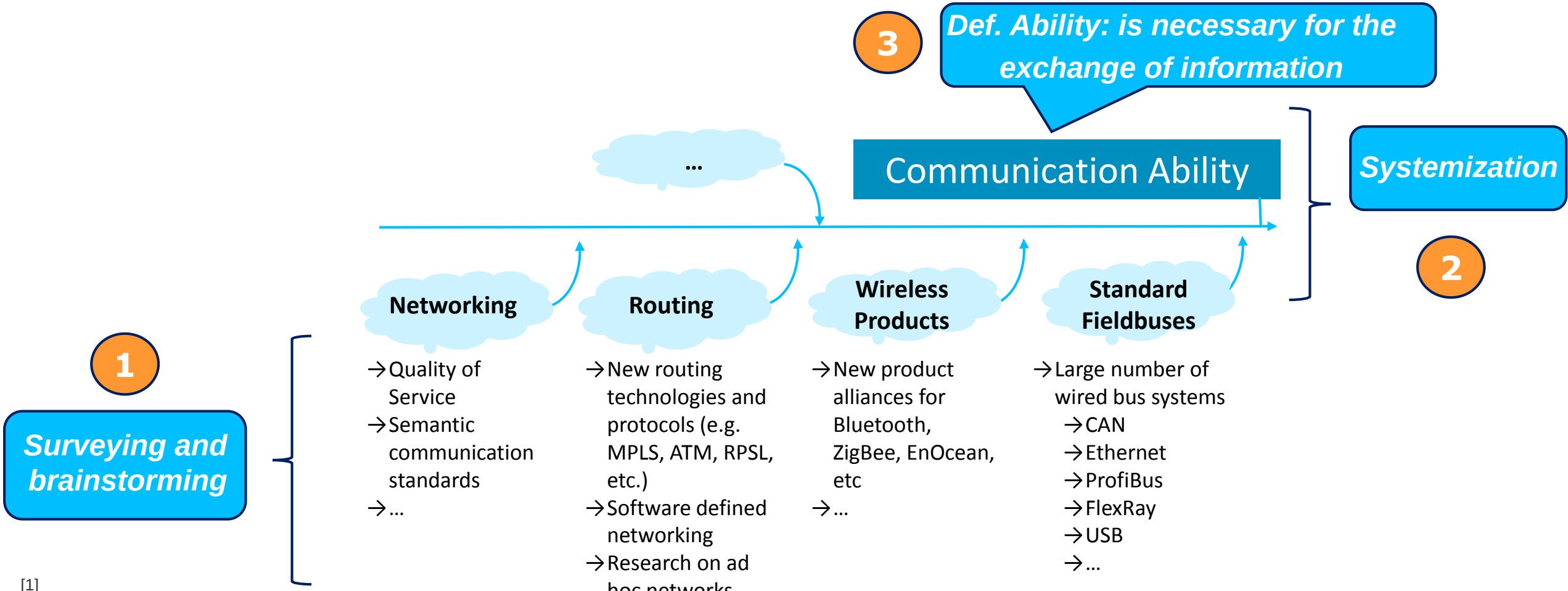


[1]

Example of the Identification of „Abilities“

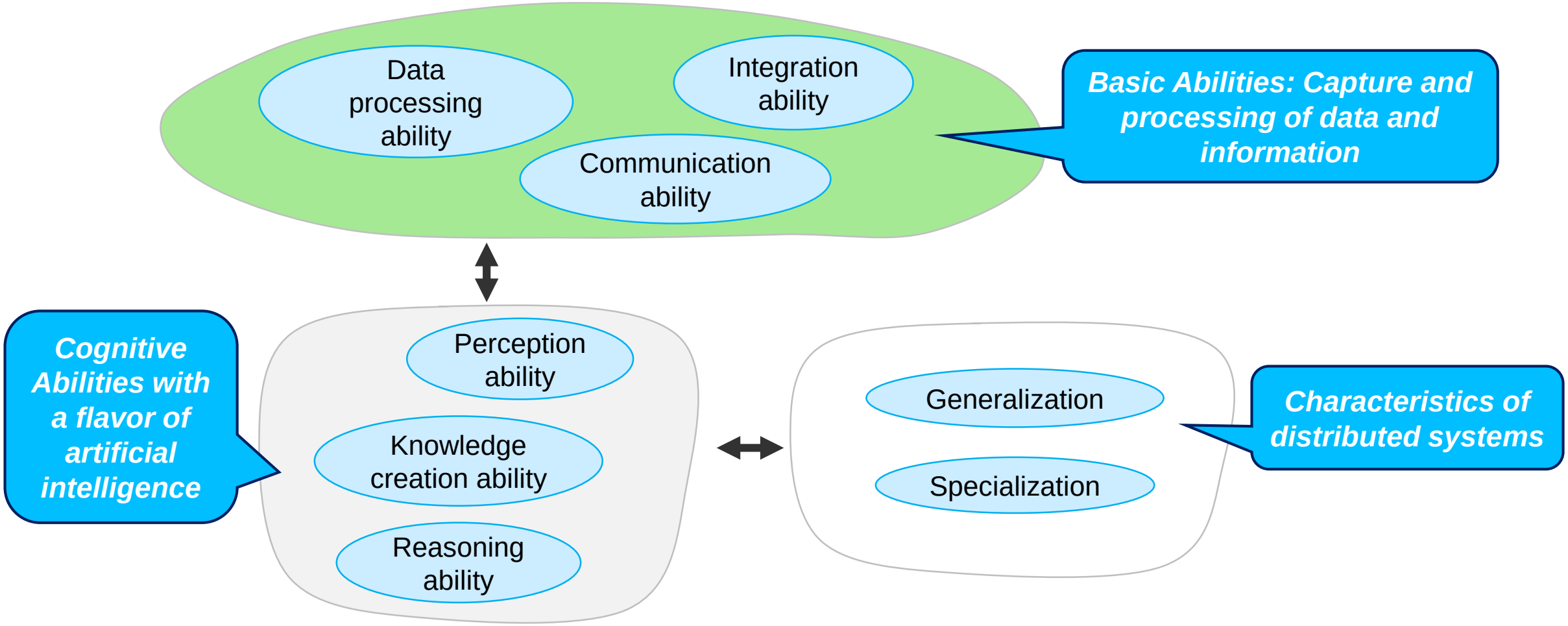
Abilities aim to provide a descriptive model explaining cyber-physical production systems from a technological viewpoint.



[1]

The Ability Model is leading to a "Score Card" for Evaluation

Eight different abilities along with a refined scoring system can be used to assess the impact of IT in an automated manufacturing system

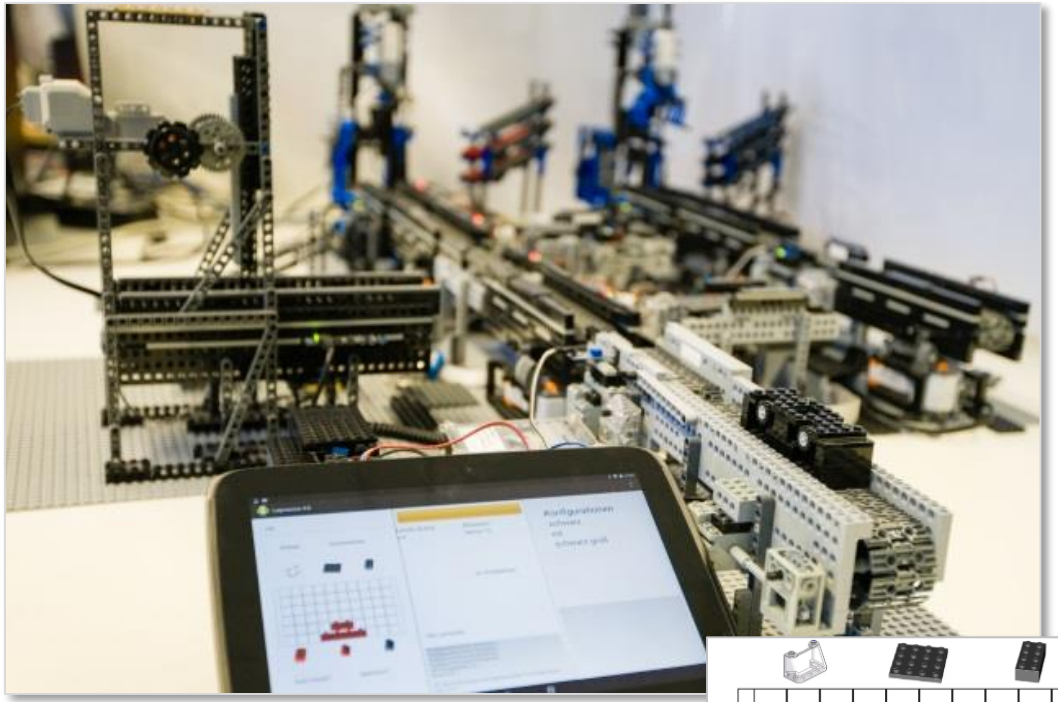


[1]

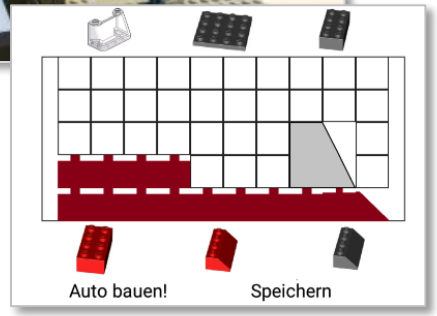
„Model Car“ Smart Manufacturing of IAS (1 of 2)

IAS has developed a Smart Factory using latest information technology.

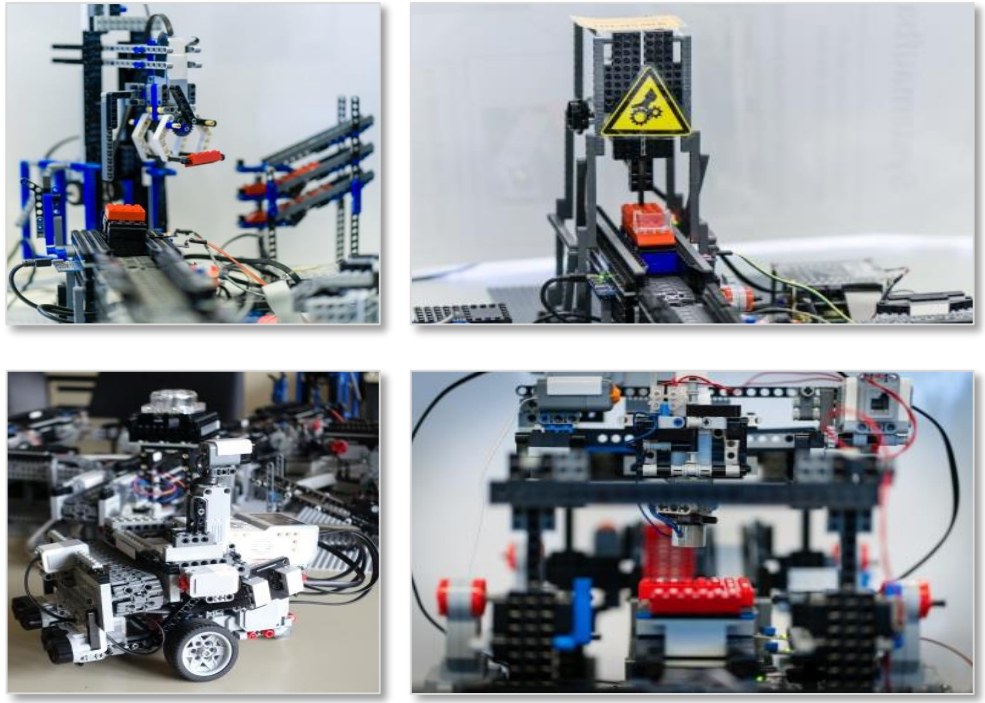
Modular Assembly System



Configurable Product

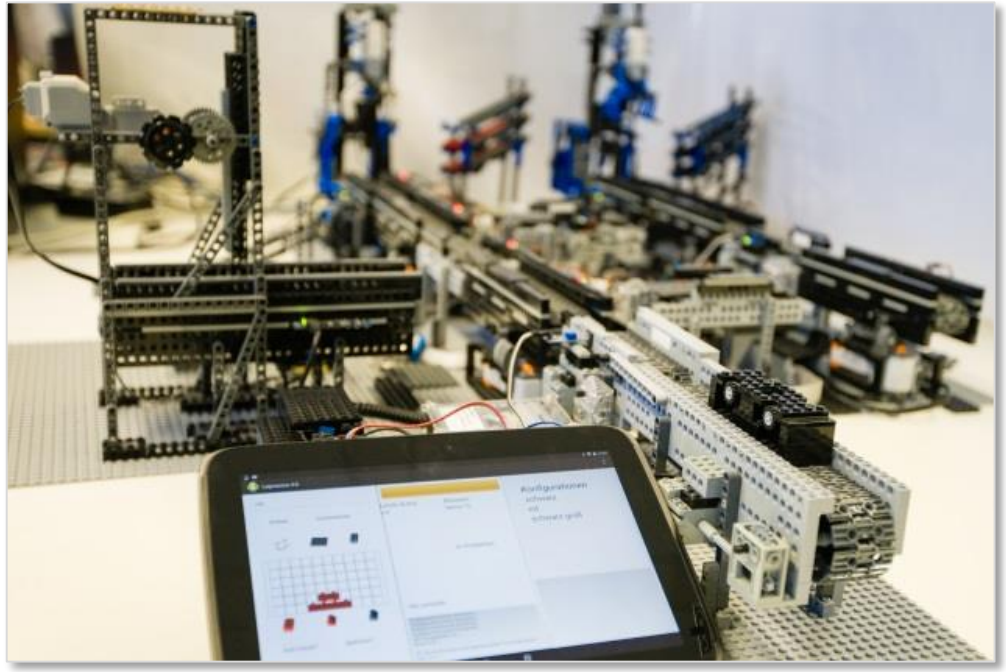


Reconfigurable Units



„Model Car“ Smart Manufacturing of IAS (2 of 2)

The automatic manufacturing system addresses a number of “Cyber Abilities”, ´by means of sensors, RFID, distributed micro controllers and agent-based control algorithms.



- Data processing ability: Level 2 – „Real time, **decentral**“
- Communication ability: Level 2 – „**Wireless**“
- Integration ability: Level 4 – „Objects managed as **Entity**“

- Perception ability: Level 2 – „**Detect objects** in the environment “
- Knowledge creation ability: Level 0 – „none“
- Reasoning ability: Level 2 – „**Algorithms based on rules**“

- Generalization ability: Level 0 – „none“
- Specialisation ability: Level 2 – „**Partially autonomy** of Modules“

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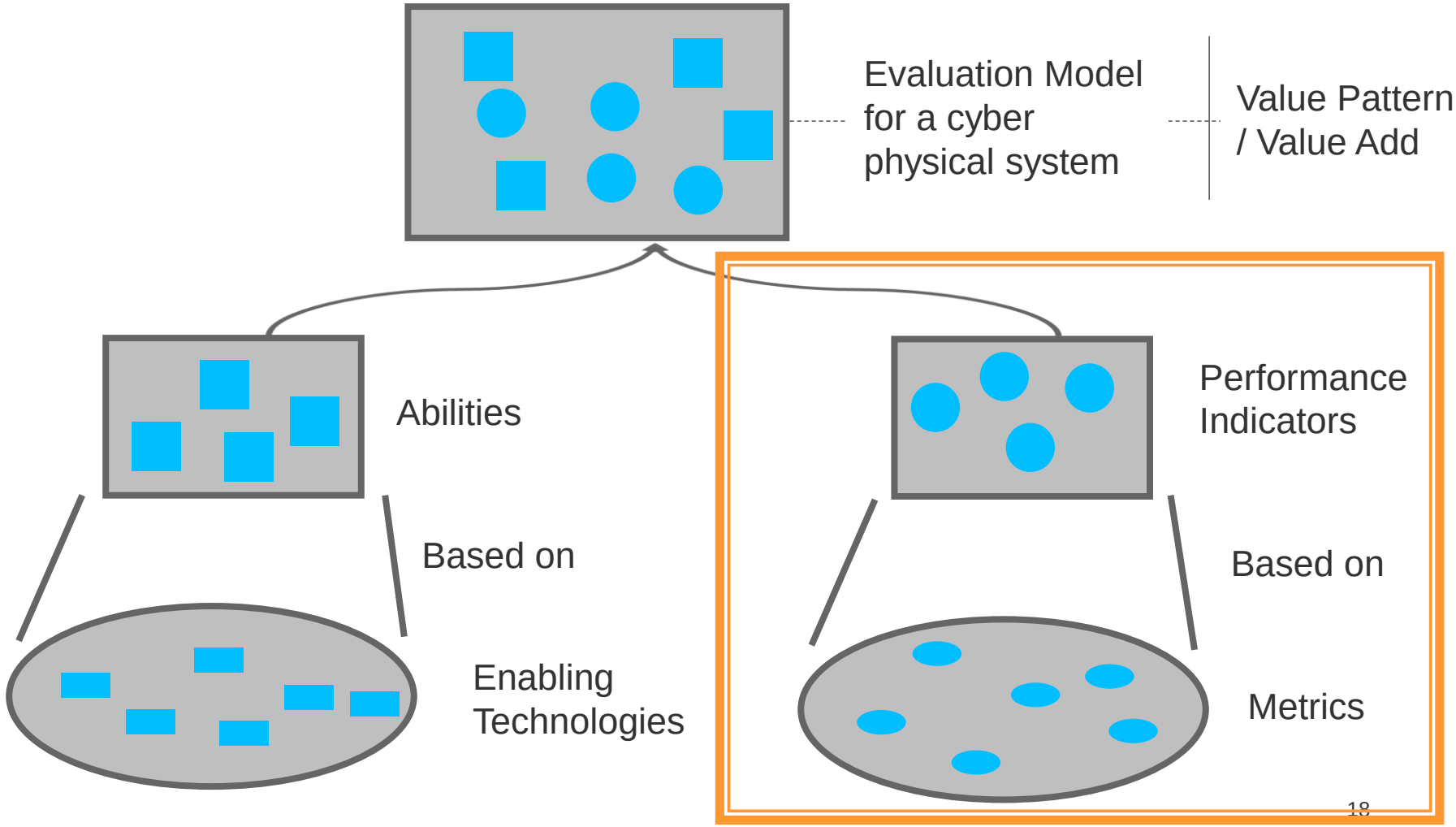
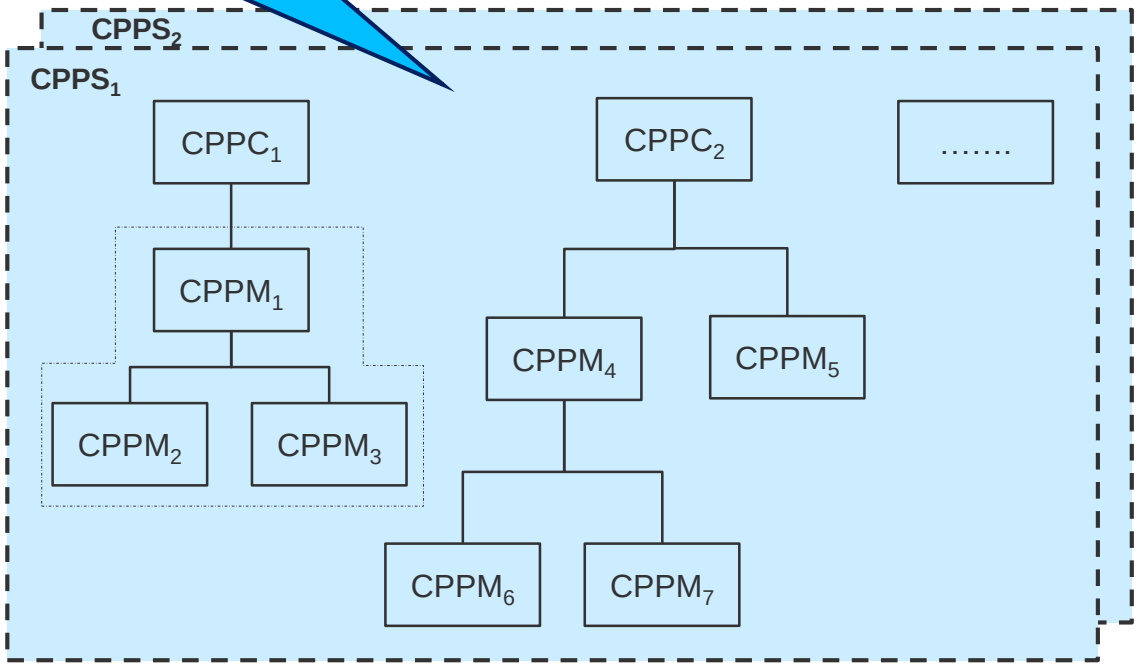


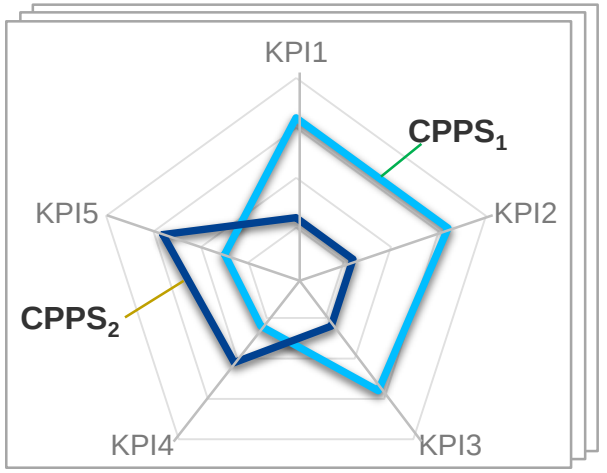
Usage of Key Performance Indicators (KPI)

KPI measure how well an organization is making progress in achieving a particular objective.

KPI in manufacturing are well established, e.g. the Overall equipment effectiveness (OEE)



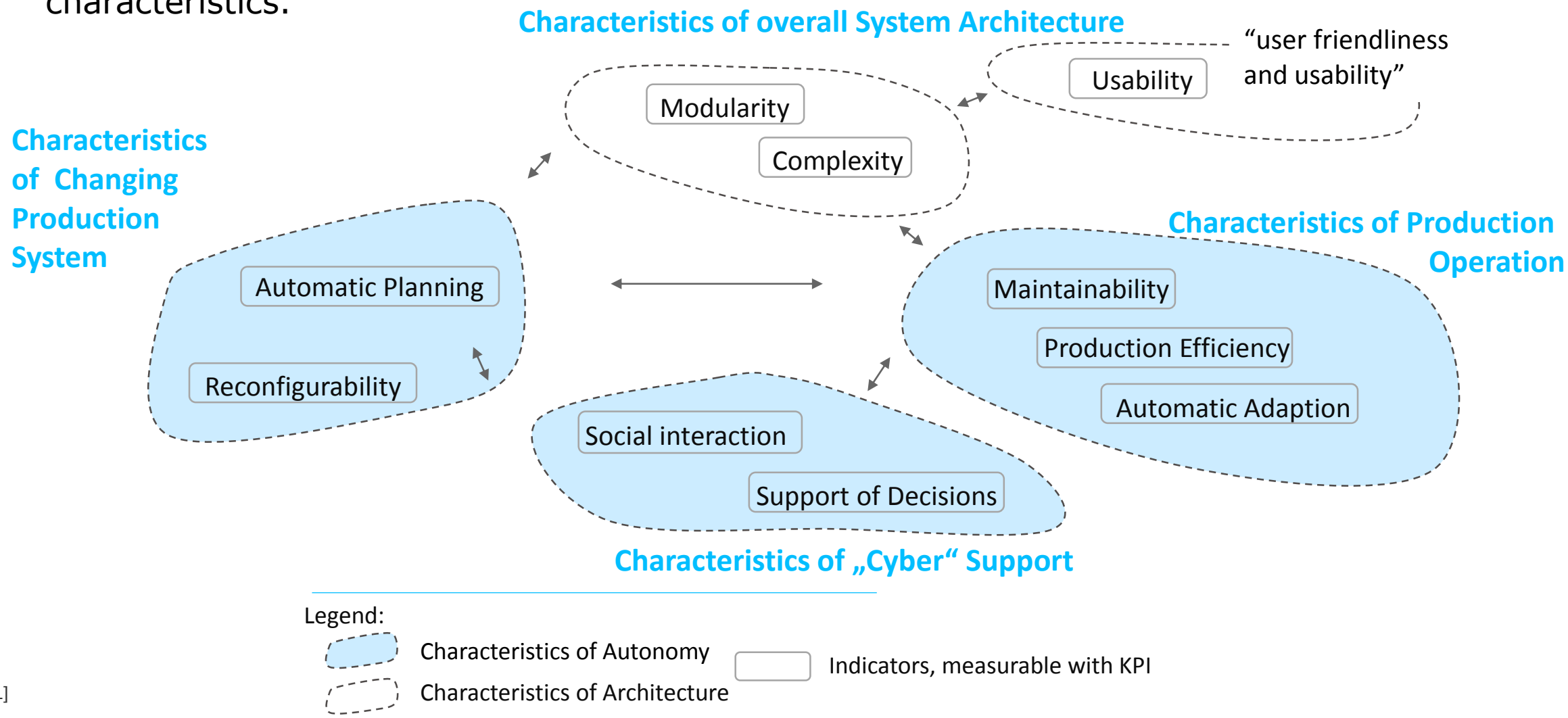
How would KPI help assessing Information technology deployed?



[1]

Measurable Performance Indicators

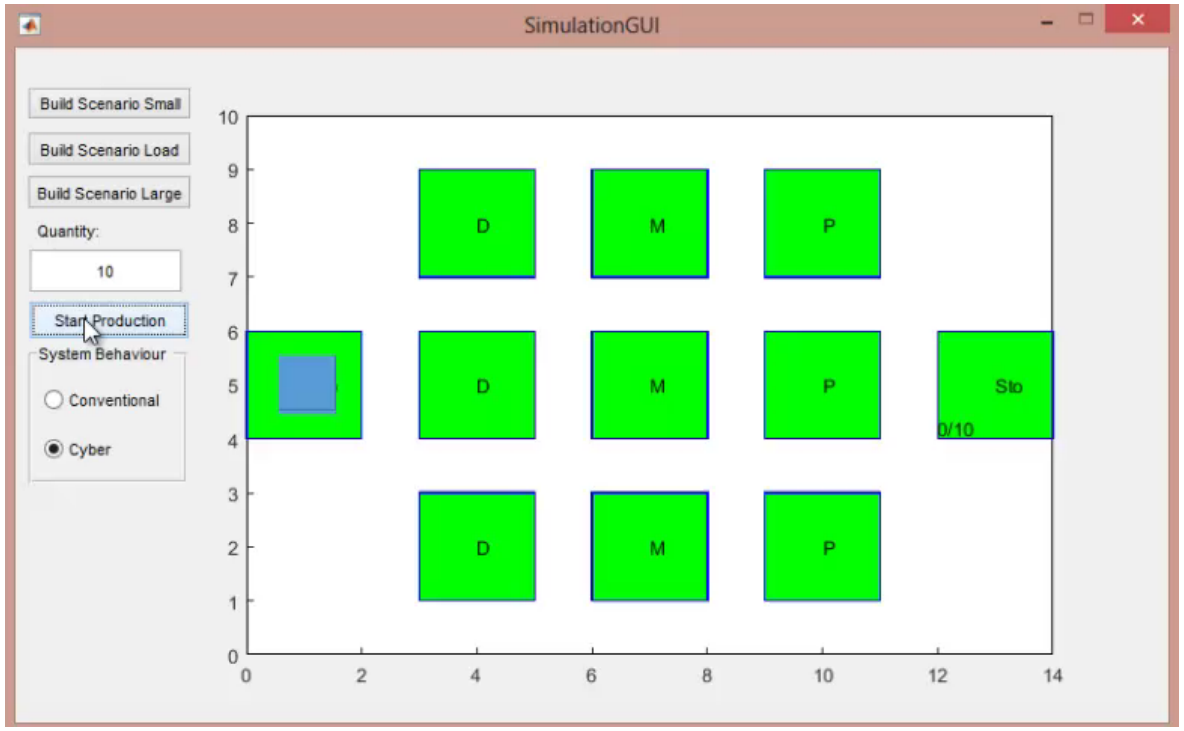
As a result of the KPI analysis, it is evident that there are different types of measurable characteristics.

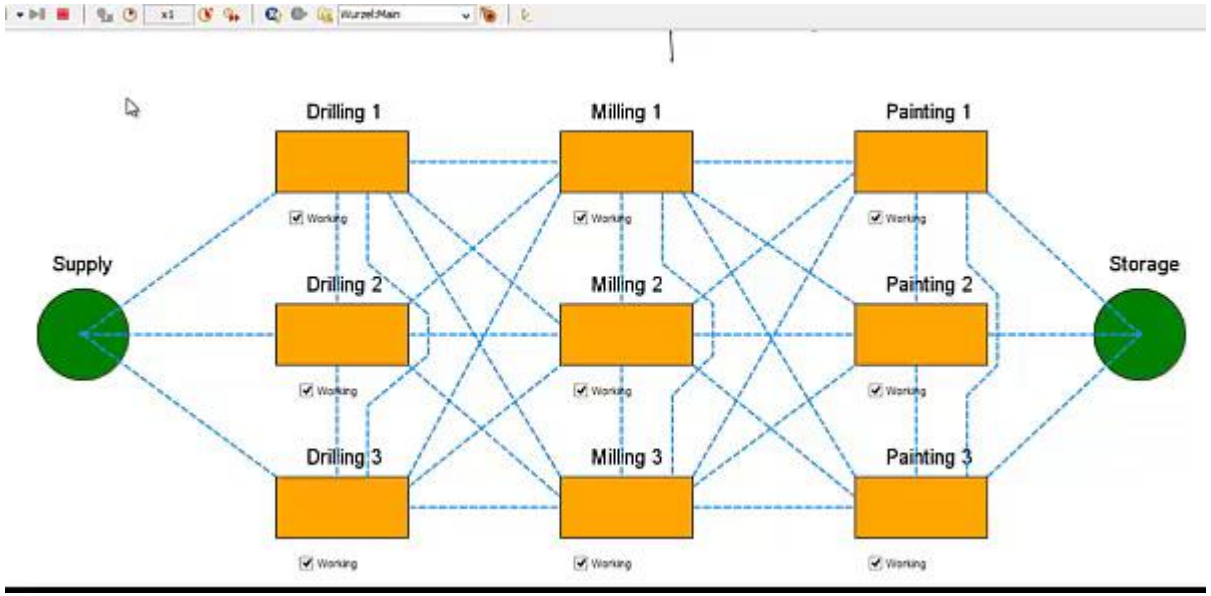


[1]

Event-discrete Simulation

Conducting an Automatic reconfiguration is analyzed in simulation

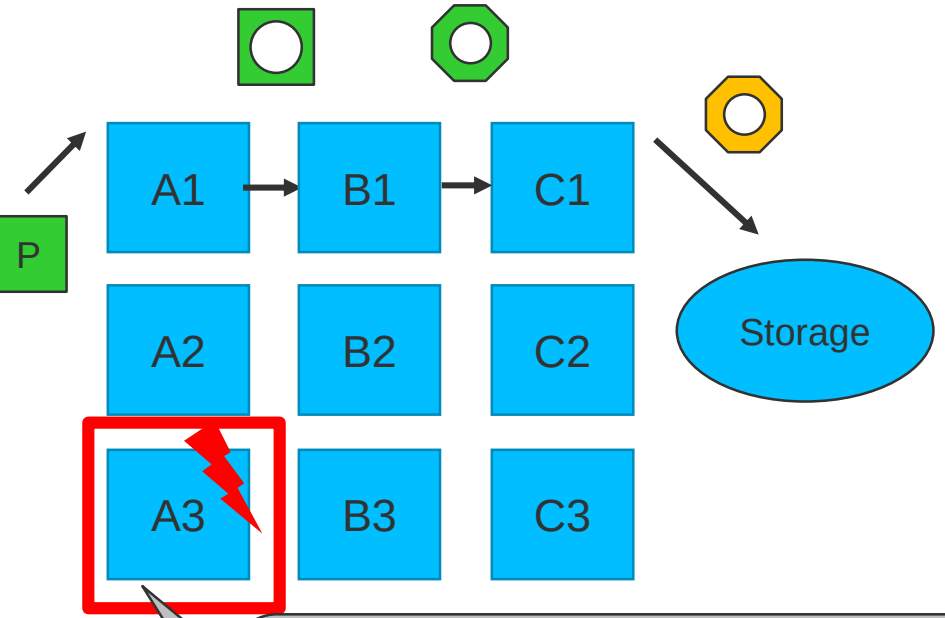




Verification in the Simulation (1 of 2)

Various abilities such a data processing, communication, perception and reasoning improve the production rate and the productivity

Simulation: Cost analysis



Event

Alternatives:

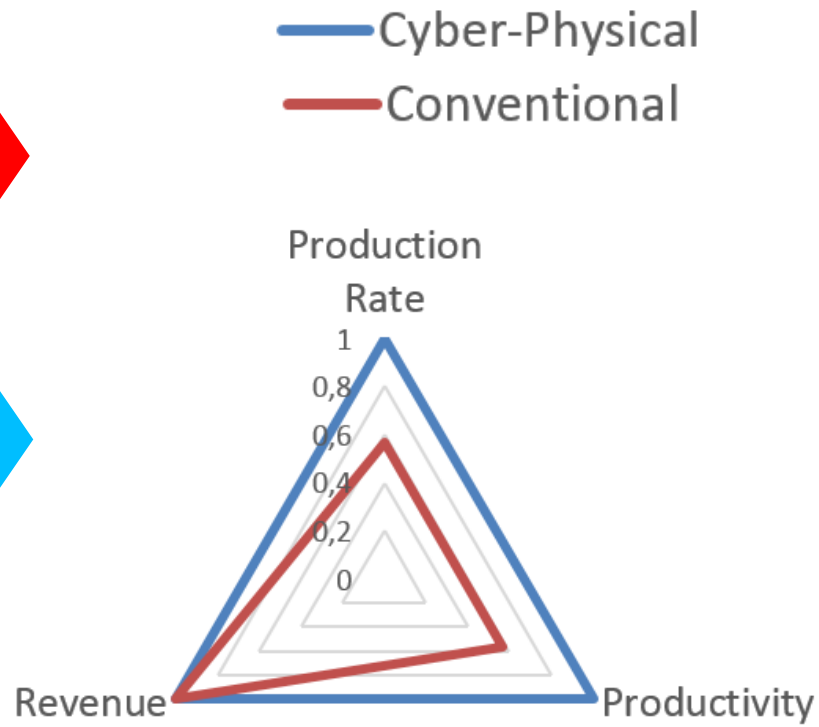
MODULE FAILURE:	Total costs of production:
Reconfiguration:	100€
Wait for repair:	200€
Outsourcing:	300€

Strategy

Conventional systems: The “wait for repair” strategy is realized in the simulation

Cyber physical system: The “conducting an automatic reconfiguration” strategy is realized in the simulation.

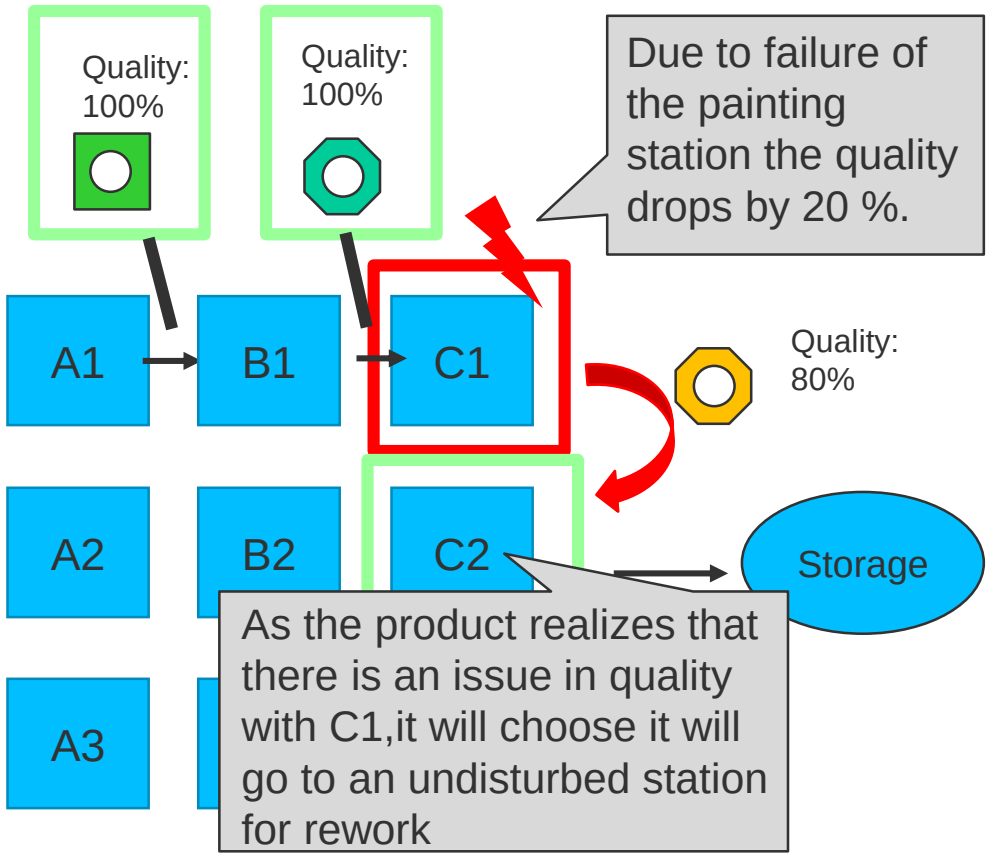
KPIs



Verification in the Simulation (2 of 2)

The failed module must realize (“Perception”) its failure and be able to inform the products (“communication”) which then has to interact to find the next station (“data processing”)

Simulation: Quality analysis

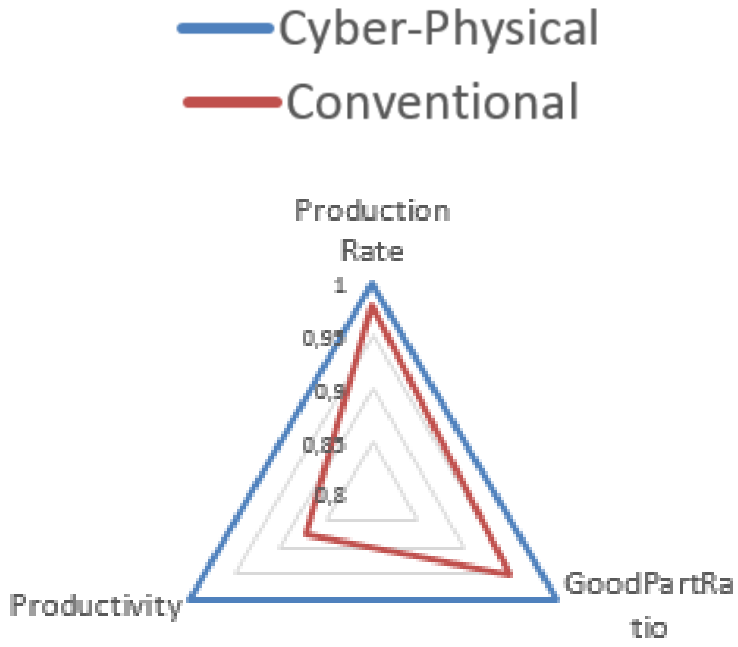


Strategy

Conventional systems: low-quality parts are dropped and lost

Cyber physical system: compensating for a moderate quality loss by reworking

KPIs



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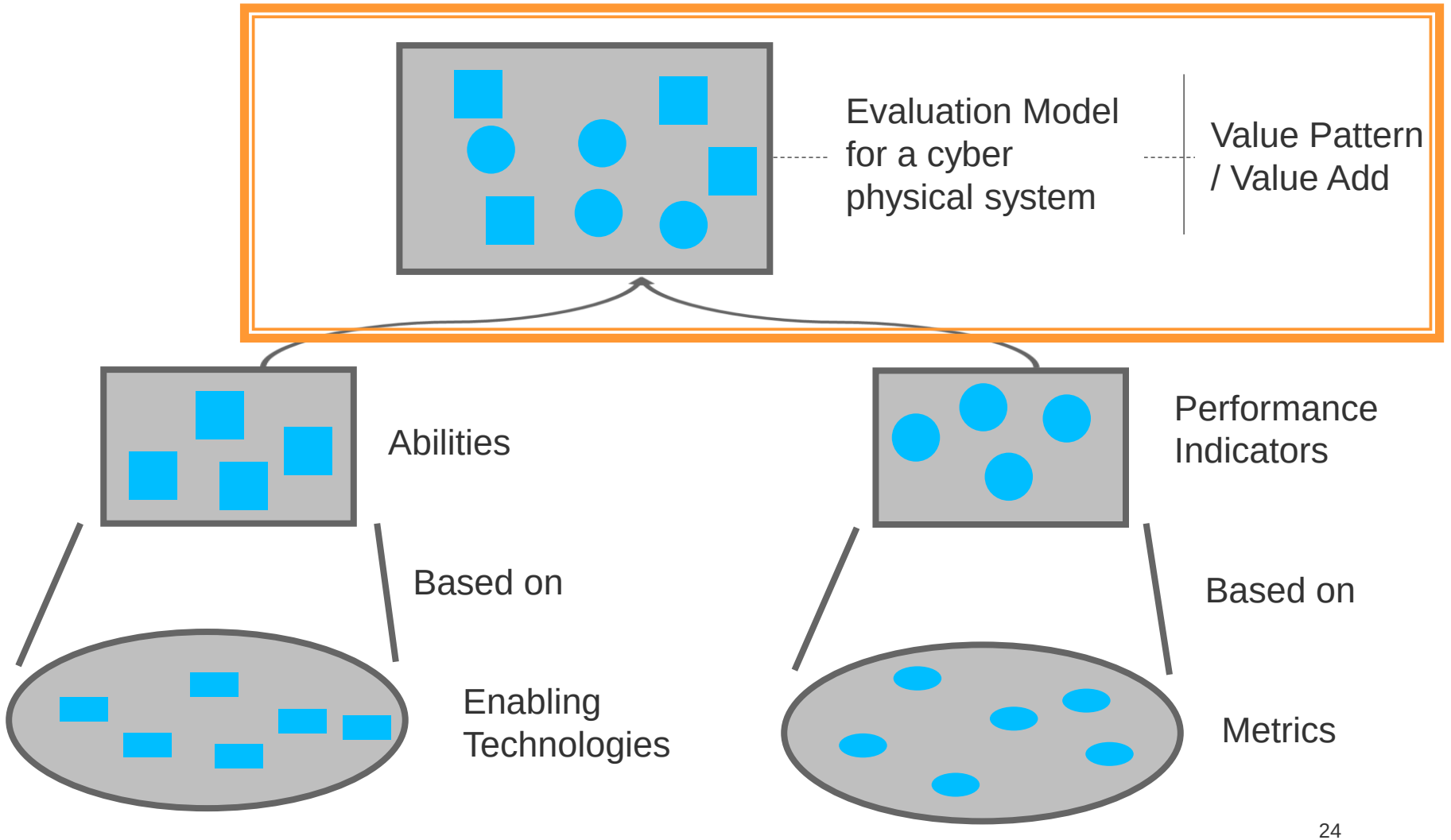


[1]

Value Patterns of „Industrie 4.0“ / „Cyber-physical Systems”

Interconnection between performance indicators and abilities reveal the four patterns which are the important aspects of the evaluation model

Pattern 1 - “Smart Modules”

Pattern 2 - “Interoperability and Self-configuration“

Pattern 3 – “Self-optimization”:

Pattern 4 - “Decision Support”

	Modularity	Communication Ability	IT Integration Ability	Automatic Adaption	Automatic Planning	Reconfigurability	Ability of Automatic Scheduling	Complexity	Maintainability	Knowledge Creation and Reasoning Ability	Social Interaction	Support of Decisions	Perception Ability	Data Processing Ability	cy
Modularity		1	1					1							
Communication Ability	1		1								1		1	1	1
IT Integration Ability	1	1											1	1	
Automatic Adaption							1		1						1
Automatic Planning						1	1								
Reconfigurability					1		1								
Ability of Automatic Scheduling				1	1	1		1		1					
	1						1								
				1						1					1
							1		1		1	1			
Interaction		1								1		1	1		
Support of Decisions										1	1				
Perception ability		1	1								1	1		1	
Data Processing Ability		1	1										1		
Production Efficiency		1		1					1						

Legend:

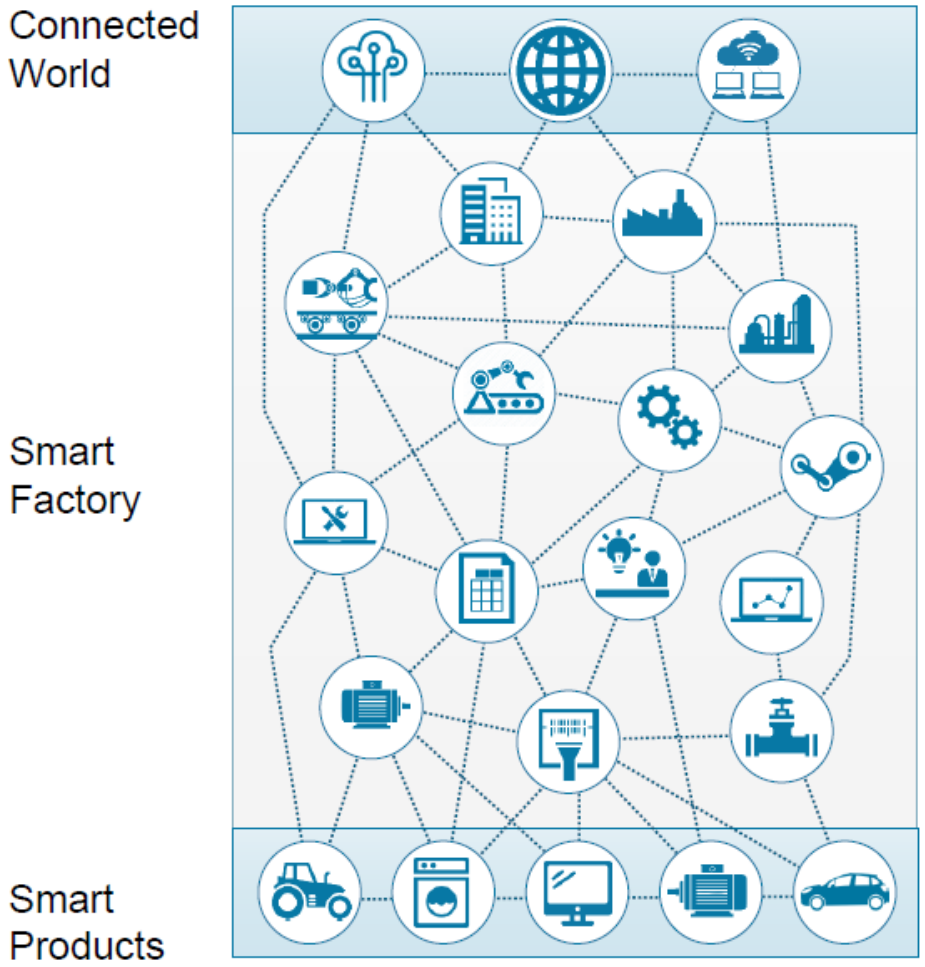
1	Laut Tabelle: Perfpormance Indicators, characteristics and related CPPx Abilities
1	According to Fig. Grouping of Abilities and further Aspects of a CPPx
1	According to Fig - Classification of measuranle Indicators

[1]

Pattern 1 - “Smart Modules”

The performance indicator of Modularity is clearly driven by two technical abilities; the Communication Ability and the IT Integration Ability.

- Flexible machinery is built-up from models
- Functions are distributed in a network
- All participating modules are interconnected
- Communication happens between all participants



Bildquelle: Anna Salari, designed by freepik

[1]

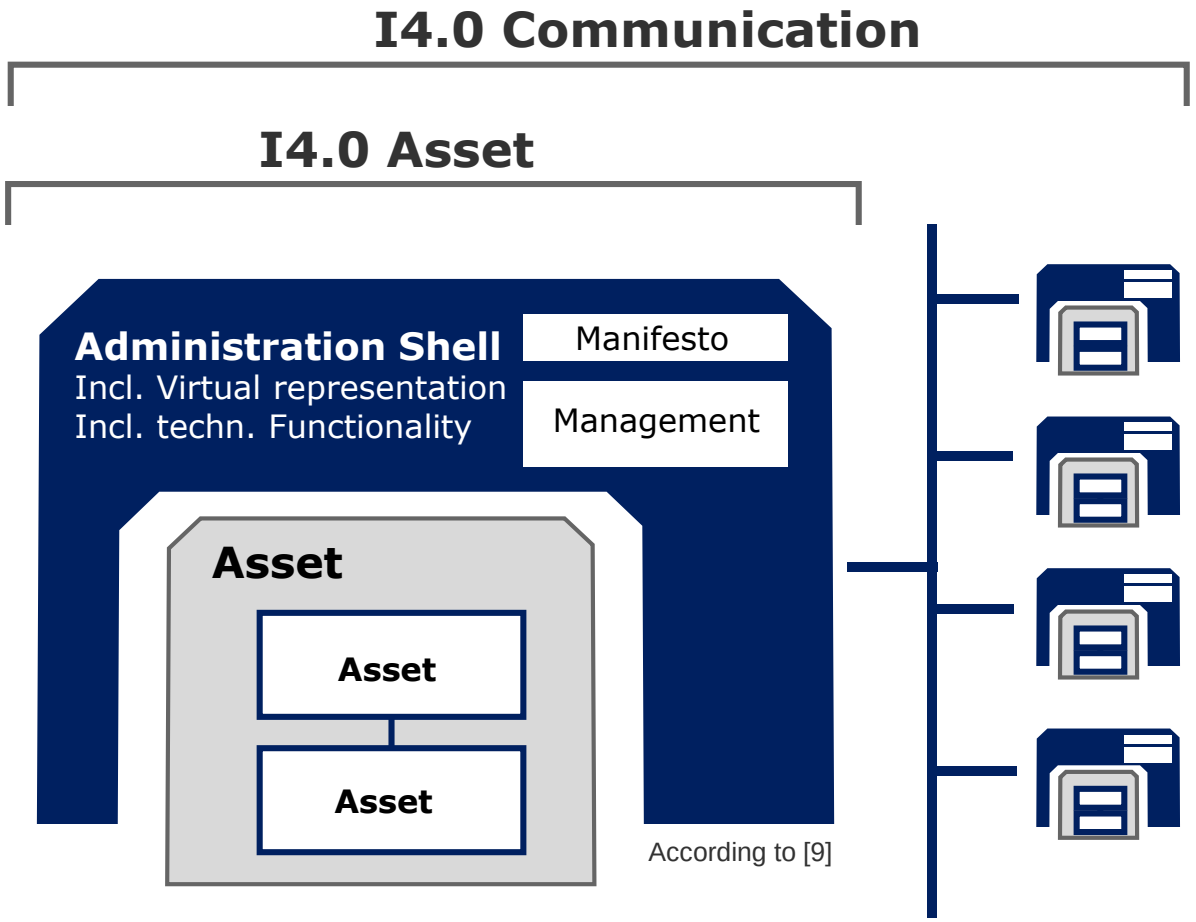
Pattern 2 - “Interoperability and Self-configuration”:

A production module or system can be used in numerous different contexts and modified to a new configuration of hard- and software itself.

Systems changeability happens all the time and is enabled by interoperability:

- Interoperability between modules requires a standardized communication
- „Industrie 4.0“ Assets are indirectly defined by their administration shell
- Standardization activities are on their way

[1]



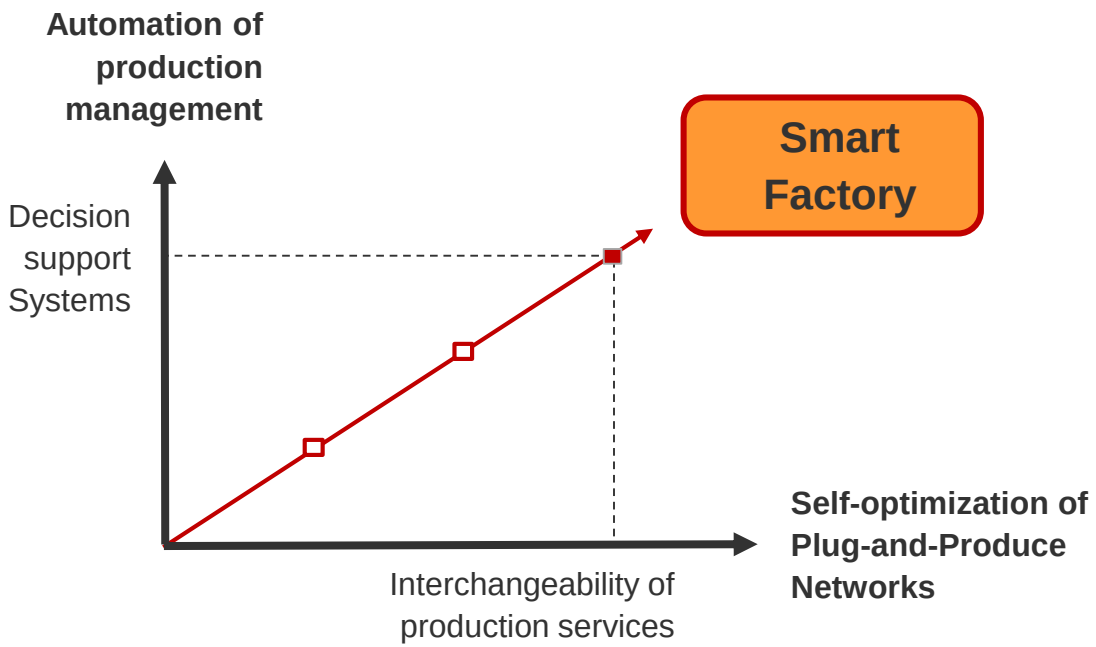
Value Patterns 3 and 4

Pattern 3 – “Self-optimization”

If a system is able to perceive its own status and process related data, it can improve its own operational performance leading to Self-Optimization

Pattern 4 - “Decision Support”

The processing of networked data and information would support any decision making. It can be viewed as social interaction related to the provision of information

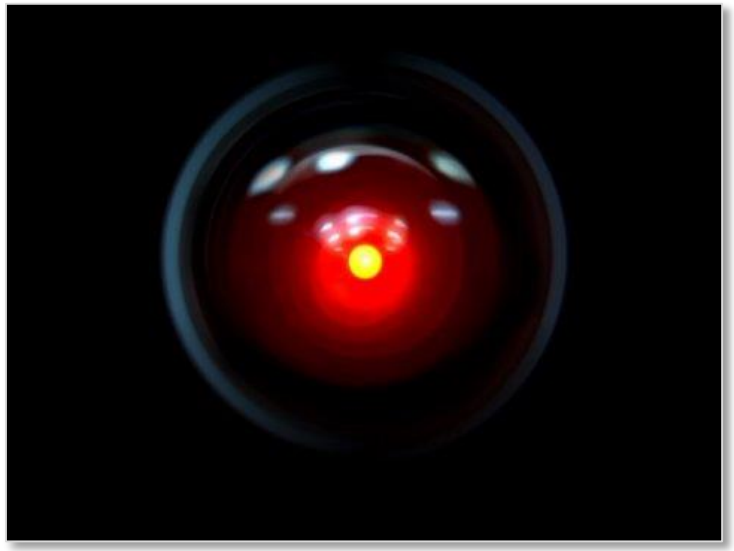


[1]

Conclusion and Outlook

- Information Technology will change automation and knowledge processing once again
- „Industrie 4.0“ has managed to set the topic of “Automation” on the political agenda
- Big Gap between Industry relevant technology and future approaches
- Trans-disciplinary cooperation required between the Information technologies, Computer Science and mechanical / production engineering

- **„Industrie 4.0“ is a long way to go …**



Google Pics

References

(1) Michael Weyrich, Matthias Klein, Jan-Philipp Schmidt, Nasser Jazdi, 4 Kurt D. Bettenhausen, Frank Buschmann, Carolin Rubner, Michael Pirker and Kai Wurm: Evaluation Model for Assessment of Cyber-Physical Production Systems. In: Industrial Internet of Things Cyber manufacturing Systems: Jeschke, S., Brecher, C., Song, H., Rawat, D.B. (Eds.), , Spinger Verlag 2016

(2) Weyrich, M.; Göhner, P.; Diedrich, C.; Vogel-Heuser, B.; Fay, A.; Wollschlaeger, M.; Kowalewski, S.: Flexibles Management einer dezentralen Automatisierungsverbundanlage als Beispiel für Industrie 4.0. Automation 2014, Baden-Baden, 2014

(3) Acatech and Forschungsunion: Recommendation for implementing the strategic initative INDUSTRIE 4.0, April 2013

(4) Bitkom und FhG IAO: Industrie 4.0 – Volkswirtschaftliches Potenzial für Deutschland Studie, 2014. https://www.bitkom.org/Publikationen/2014/Studien/Studie-Industrie-4-0-Volkswirtschaftliches-Potenzial-fuer-Deutschland/Studie-Industrie-40.pdf

(5) BCG study: Industrie 4.0: The Future of Productivity and Growth in Manufacturing Industries, 2015. https://www.bcgperspectives.com/Images/Industry_40_Future_of_Productivity_April_2015_tcm80-185183.pdf

(6) Landkarte Industie 4.0: http://www.plattform-i40.de/I40/Navigation/DE/In-der-Praxis/Karte/karte.html

(7) BitCOM Industrie 4.0 - Status und Perspektiven. Studie, 2016. https://www.bitkom.org/Publikationen/2016/Leitfaden/Industrie-40-Status-und-Perspektiven/160421-LF-Industrie-40-Status-und-Perspektiven.pdf

(8) Deutsche Bank Research: New challanges for a land on expedition. Frankfurt 2077. https://www.dbresearch.com/PROD/DBR_INTERNET_EN-PROD/PROD0000000000210852/Germany_2020_-_New_challenges_for_a_land_on_expedi.pdf

(9) Plattform Industrie 4.0: Struktur der Verwaltungsschale Fortentwicklung des Referenzmodells für die Industrie 4.0-Komponente. 2016 http://www.plattform-i40.de/I40/Redaktion/DE/Downloads/Publikation/struktur-der-verwaltungsschale.pdf?__blob=publicationFile&v=7

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