Seamless Engineering in the Industry 4.0 Era

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Seamless Engineering in the Industry 4.0 Era

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ABOUT US

Our competences, our visions
The Research University in the Helmholtz Association.
Make analytics come alive with Digital Twin Ecosystem.
“Sandbox” for experiments in run-time environment.

Source: Industrie 4.0 Collaboration Lab (KIT)
Virtual Environments Lab
CAVE VR system

Mixed Reality Lab
Driving Simulation,, HTC, HoloLens, haptic Interaction

Communication Lab
Co-Working-and-Sharing-Space

International Cooperation Lab
China, France, Bulgaria, etc.

Experience Lab
Digital Twin Solutions

Content Creation Lab
Development and Training with CAx/PLM

Value Creation Lab
Industrial Case Studies and Implementation

Tea Lab
Creativity-Think-Tank

Source: Ovtcharova 2018
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Why, What, How?
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Why, What, How?
The Beginning of Industry 4.0

Dream team:
- Prof. Kagermann, acatech
- Prof. Wahlster, DFKI
- Prof. Lukas, BMBF
at the Hannover Fair in 2011

Smart manufacturing in focus:
- System interoperability I Internet of things
- Information transparency I Cloud computing
- Technical assistance I Cognitive manufacturing
- Decentralized decisions I Cyber-physical systems

Computers and automation come together in a new way.

Source: acatech
Causes and Consequences

Industrie 1.0
Mass production
Mechanization
hydro- and steam power
End of the 18th century

Industrie 2.0
Mass distribution
Electrification
electrical power and vehicle mobility
Beginning of the 20th century

Industrie 3.0
World economy
Automation
computer and information technology
Beginning of the 70's

Industrie 4.0
Real-time economy!
Cyberization
smart devices and humans, real time interconnections
Today

Source: Ovtcharova 2021

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Real-time Economy

INTERNET-MAP 2003

INTERNET-MAP 2015

25 billion devices and 5 billion people on-line.

Source: Gartner, Pictures: Festo / blog.kaspersky.com

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The World is „All-in-One“

Real and artificial objects co-exist in real time and in space.

**MERGING OF MATERIAL AND VIRTUAL (COMPUTER GENERATED WALK-IN) REALITIES**

**PERCEPTION AND COMMUNICATION IN REAL TIME AND IN SPACE**

**INTUITIVE HUMAN-COMPUTER INTERACTION (LOGICAL, COMPREHENSIBLE, INTUITIVE) IN RUNTIME ENVIRONMENT**

*Pictures: Chess Wise BV, LESC (KIT), Arku GmbH*
Digital Twin: Status Quo

Mature and widespread implementation is missing.

MODEL SEMANTICS IS MOSTLY GEOMETRY DRIVEN

ANALYTICS IS ALIGNED AND NOT EMBEDDED

SIMULATION AND USER INTERACTION ARE OFFLINE

Pictures: Dassault Systèmes, IBM Watson IoT, GE
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Why, What, How?
Definition

Digital representation of real units and processes interacting and synchronized with a certain accuracy and frequency:

• is system-of-systems,
• uses real-time and historical data,
• represents the past and present,
• simulates the future in a predictive way,
• is implemented in IT/OT systems.

Source: https://www.digitaltwinconsortium.org/glossary/index.htm#digital-twin © Jivka Ovtcharova I 16
The existence of a powerful infrastructure based on open, international standards is a prerequisite to:

- support human-twin interaction,
- meet non-functional requirements such as data sovereignty, privacy, and data usage control,
- ensure interoperability and synchronization.

Source: https://www.digitaltwinconsortium.org/glossary/index.htm#digital-twin
Cybernetic model 60s

Bidirectional connectivity, at any moment!

Source: Norbert Wiener, MIT, Cybernetic model 60s, according to S. Böckl, 2005

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Technical capabilities that differentiate 5G

Catalyst for economic growth is connectivity enabled by 5G.

5G leads to new frontiers of productivity and innovation.
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Why, What, How?
Three fundamentals

Setting new norms, hands-on practices and skills.

Source: own presentation
FUNDAMENTAL #1

Reference Architectural Model Industry 4.0 (RAMI 4.0)
Derive rules for Industry 4.0 implementations.

Reference Architecture Model Industry 4.0 (RAMI 4.0) VDI, VDE and ZVE ensures that all participants involved in Industry 4.0 discussions understand each other.
Asset Administration Shell

Stores all data and I4.0 interfaces about assets.

Source: visit, 2018

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Industry 4.0 Component

Contain physical assets with their administration shells.

Communication capability of cyber-physical systems is described by real objects, which are networked with virtual objects and processes.
Bi-directional connectivity of Industry 4.0 components.

Real-time-capable handling of material and service systems in different versions over the entire life cycle.
Digital Twin

Bi-directional connectivity of Industry 4.0 components.

<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Universality</td>
<td>Generation, editing, distribution and playback</td>
</tr>
<tr>
<td>Availability</td>
<td>Accessibility in different formats and data carriers from everywhere</td>
</tr>
<tr>
<td>Usability</td>
<td>Multiple and multi-sided use, small space requirement</td>
</tr>
<tr>
<td>Portability</td>
<td>Automatic processing, low transmission errors</td>
</tr>
<tr>
<td>Intelligence</td>
<td>Quick search, evaluation, analysis and learning ability, mapping of decision and action sequences (algorithmization).</td>
</tr>
</tbody>
</table>
FUNDAMENTAL #2

Hands-on Practice
The „German Mittelstand“ is a Trademark

99.6% of all companies

58.5% of all workplaces

81.8% of all trainees

35.3% of total sales

German thoroughness is no longer enough.

Source: BMWi/Eriksson, 10.04.2017, Pictures: Volksbank Münster
Example: Industry 4.0 for SMEs

Company profile

- 46 Participants
- 50% deal with VR
- above-average Interest
- Industrial sectors:
  - Mechanical Engineering and Plants (26%)
  - Information Technology (17%)
  - Civil Engineering & Architecture (12%)
  - Services (12%)
  - Automotive (7%)
  - Electronics (7%)
  - others (19%)

Number of employees

- 15.2% 0 - 9
- 15.2% 10-49
- 19.6% 50 - 249
- 32.6% 250 - 499
- 8.7% 500 - 999
- 6.5% 1000 und mehr

Source: Analyse der Wirtschaftlichkeit der Virtual-Reality-Technologie im Kontext von Industrie 4.0, Masterarbeit J. Dücker, KIT, 2015
Example: Industry 4.0 for SMEs

**Identified hurdles**
- Insufficient knowledge about the topic
- Enormous time effort
- High investment risk
- Low acceptance among employees
- Low acceptance also among customers and suppliers
- No experiences in integration into business processes
- Lack of human resources and capacity
- Lack of appropriate software solutions
- Lack of practical experiences
- Missing professional skills and qualification
- Missing data preparation and analysis
- No meaningful applications
- Others

**Analysis of the results**

Source: Analyse der Wirtschaftlichkeit der Virtual-Reality-Technologie im Kontext von Industrie 4.0, Masterarbeit J. Dücker, KIT, 2015
New practice for Industry 4.0

Traditional implementation  
Investment  
Deployment  
Added value?

Required implementation  
Deployment  
Added value!  
Investment  
VIRTUAL DEPOT

„A virtual depot - what to practice“ is necessary.

Source: own representation
„Sandbox“ Implementation

• Put real problems "in the sandbox" of business units
• Think, try out, create “All-in-One”
• Apply emerging technologies playfully and quickly
• Test new solutions in runtime to gain experiences fast
• Transform knowledge into actions and skills
• Establish “Deep Digital Twin Engineering” as a trademark

New skills for today's competition!
FUNDAMENTAL #3

New skills
Complete data acquisition, end-to-end process simulation.
Deep Analytics

Self learning algorithms, Knowledge-based Engineering.

Source: Ovtcharova 2021
Virtual Environments

Merge of virtual and physical realities.

Source: Ovtcharova 2021
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Drive actions and deliver value
Human-centred engineering methods

Real-time networking of data, assets, services and people.
Example IMI I KIT

Virtual Reality Student Project - Virtual twin of a milling machine

Product and process simulation in real time.

Videos: Industrie 4.0 Collaboration Lab (KIT)
Commissioning with Digital Twin

- RAMS (Reliability, Availability, Maintainability, Safety) live
- Validation of machines and entire production lines
- Data homogenization and quality check
- Virtual testing of machine code
- Reduction of complexity and production errors
- Adaptation and reduction of interfaces
- Increasing transparency for end customers
- Increasing visibility and competitiveness

Do it right the first time!

Pictures: Industry 4.0 Collaboration Lab (IMI/KIT)
Qualifying with Digital Twin

- Holistic training during and after development
- Early generation of technical documentation
- Shortening the time to real use
- Improving user-friendliness for different groups: Developers, Engineers, Operators, Administrators, Suppliers, Managers
- Optimization of condition monitoring and predictive maintenance scenarios

Learn it right the first time!

Pictures: Industry 4.0 Collaboration Lab (IMI/KIT), Video: IMI/KIT with Siemens AG – Power Generation Services Division / Siemens Power Academy, Karlsruhe

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Monitoring with Digital Twin

• For required 20 year service life
  Installation costs = repair costs (1 Mio. €/MW)
• The operation costs: dramatically high
  Crane 10.000 € / day, ship off-shore 100.000 € / day
• Damage costs due to failure: immense
• Simulation instead of putting „hands-on“
  Transfer measurement data and simulate real processes

Act in real-time!

*Pictures: Industry 4.0 Collaboration Lab (KIT)*