INDUSTRIE 4.0 – FROM THE PERSPECTIVE OF APPLIED RESEARCH

Prof. Reimund Neugebauer

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Berlin, September 7th 2016
INDUSTRIE 4.0 – FROM THE PERSPECTIVE OF APPLIED RESEARCH

1  Facts and Figures about Fraunhofer

2  Industrie 4.0 – Industrial Transformation

3  Requirements for data-driven production

4  Industrie 4.0 – examples of applied research

5  Conclusion
Fraunhofer-Gesellschaft

24,000 people work at 67 places for innovation

Application oriented research – direct benefit for companies and society

24,000 staff

67 institutes and research units

Financial Volume 2015

- > 70% research projects: - industry - publicly-financed
- < 30% base funding
- Infrastructure expenditure and defense research

2.1 bn

1.8 bn
Revenues*: 

291 Mio €
2/3 Europe and
1/3 Rest of the World

*2015, without subsidiaries, without licensing
Our research covers future challenges
Challenges in Industrie 4.0 technologies

Health and Environment
- e.g. Human-Machine-Interaction/Cooperation

Production and Supply of Services
- e.g. Cyber Physical Systems, predictive maintenance, customized and adaptive production ...

Communication and Knowledge
- e.g. data security and safety, data rate and latency, deep learning ...

Energy and Resources
- e.g. closed-loop production, energy self-sufficiency, intelligent grids

Mobility and Transport
- e.g. autonomous vehicles, decentralized multi-agent logistics ...

Security and Protection
- e.g. cyber security, trusted data exchange, resilient systems ...
INDUSTRIE 4.0 –
FROM THE PERSPECTIVE OF APPLIED RESEARCH

1 Facts and Figures about Fraunhofer

2 Industrie 4.0 – Industrial Transformation
   ▪ Frame conditions
   ▪ Enterprise Level
   ▪ Potentials and challenges

3 Requirements for data-driven production

4 Industrie 4.0 – examples of applied research

5 Conclusion
Drivers of the 4th Industrial (R)evolution

Socio-economic framework
- Innovation players
- Demographic change
- Changing consumption

R&D and technology
- Acceleration through ICT
- »Intelligent« technology
- Shorter innovation cycles

Industry
- New products
- New processes
- New markets

Market
- competition
- expectations
- changes
2 Industrial Transformation – Frame Conditions
National platform Industrie 4.0

Management
BM Gabriel, BM’in Wanka

Industry: Bernd Leukert (SAP), Reinhard Clemens (Telekom), Eberhard Veit (Festo), Siegfried Russwurm (SIEMENS)

Research: Reimund Neugebauer

Technical-practical competency, decision-makers

Steering Committee (Business)

Working Groups

Political governance, society, opinion leaders

Strategy Group (Politics, associations, unions, research)
Fraunhofer: Prof. Bauernhansl, IPA

Scientific Advisory Board

Industrial consortia and initiatives

INDUSTRIAL DATA SPACE

International standardization

Committee as service provider
2 Industrial Transformation – Frame Conditions

Industrie 4.0 – IT merges with manufacturing technology

- **Single Source of Truth**
  - ERP Systems
  - PLM Systems
  - Engineering Systems

- **IT-Globalisation**
  - Data storage
  - Data distribution
  - Data analysis

- **Collaboration-productivity**
  - Human / Human
  - Human / Machine
  - Machine / Machine

- **Cooperation**
  - Business Communities
  - Social Communities

- **Automation**
  - Adaptive
  - Intuitive
  - Robustness

- **Software**
- **Hardware**
2 Industrial Transformation – Enterprise Level

Dimensions of Industrie 4.0: Fraunhofer »Layer Model«

Enterprise Transformation

- **Business models**
  - New products and services

- **Management**
  - Agile production management

- **Human resources**
  - Less routine activities, more cognitive challenging contents

2 Industrial Transformation – Enterprise Level

Dimensions of Industrie 4.0: Fraunhofer »Layer Model«

Enterprise Transformation

- Business models
- Management
- Human resources

Information and Communication enabling Technologies

- Standardization
- Data rates and low latency communication
- Data security
- etc.
2 Industrial Transformation – Enterprise Level

Dimensions of Industrie 4.0: Fraunhofer »Layer Model«

Enterprise Transformation
- Business models
- Management
- Human resources

Information and Communication enabling Technologies
- Standardization
- Data rates and low latency communication
- Data and cyber security
- etc.

Data-driven Production Technologies for Industrie 4.0
- Cyber-Physical-Systems
- Machine Learning in Production Processes
- Autonomous Systems
- etc.

German economic potential of Industrie 4.0

Forecast until 2025:

- Up to **430,000 new jobs**, but simultaneous elimination of **490,000 low-skilled jobs***
- **GDP growth** of about **30 billion EURO** **
- Total investment of about **250 billion EURO** **

### Nine settings where added value is expected

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<td><strong>Vehicles</strong></td>
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<td><strong>Homes</strong></td>
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<td><strong>Offices</strong></td>
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**Size in 2025, $ trillion**

- **Low estimate**
- **High estimate**

**Total $ 4 trillion - $ 11 trillion**

1 Adjusted to 2015 dollars, for sized applications only; includes consumer surplus. Numbers do not sum to total, because of rounding.

Source: McKinsey Global Institute analysis, June 2015
2 Industrial Transformations – Potentials

Protecting know-how and competitive advantage

Traditional strengths:
Hardware, industrial machines
microelectronics, embedded systems, sensors, automotive

Internet of Things
Machine Learning

Industrial technologies
Mechanical Engineering

Traditional strengths:
Software, networks, server, clouds, Big Data, Artificial Intelligence, IT-Services
## 2 Industrial Transformations – Potentials and challenges

### Directions for the future of manufacturing

<table>
<thead>
<tr>
<th>Player</th>
<th>Situation</th>
<th>Goals</th>
<th>Means</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Industrie 4.0</strong></td>
<td>Germany</td>
<td>Growing competition</td>
<td>Integrating ICT into manufacturing</td>
</tr>
<tr>
<td><strong>Industrial Internet</strong></td>
<td>USA, UK</td>
<td>Service-centred economy</td>
<td>Adding manufacturing to ICT</td>
</tr>
<tr>
<td><strong>Full Automation</strong></td>
<td>East Asia</td>
<td>Labour shortage, rising labour costs</td>
<td>Using robots for manufacturing</td>
</tr>
</tbody>
</table>
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3 Requirements for data-driven production
   ▪ Standardization
   ▪ Data security and safety
   ▪ Data rate and low latency communication
   ▪ Machine Learning

4 Industrie 4.0 – examples of applied research

5 Conclusion
# Requirements for data-driven production

**INDUSTRIAL DATA SPACE** – Digital and Data Sovereignty

## Digital Economy – Smart Services

<table>
<thead>
<tr>
<th>ENABLER</th>
<th>Broadband expansion - Data Rate</th>
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</thead>
<tbody>
<tr>
<td>Automotive companies</td>
<td>Pharmaceuticals &amp; Medicine</td>
</tr>
<tr>
<td>Electronics and ICT</td>
<td>Mechanical engineering</td>
</tr>
<tr>
<td>Services</td>
<td>Logistics</td>
</tr>
</tbody>
</table>

### Service- and product innovation

- **»Smart Data Services«** (alerting, monitoring, data quality etc.) → **New markets**
- **»Basic Data Services«** (information fusion, mapping, aggregation etc.) → **Machine Learning**

### Internet-of-Things

- Device proxies · Network protocols

### Embedded Systems

- Sensors · Actuators

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**INDUSTRIAL DATA SPACE**

**Tactile Internet – low latency**

**Broadband expansion - Data Rate**

**Internet-of-Things** · Device proxies · Network protocols

**Standardization Council Industrie 4.0** → **Standards**
3 Requirements for data-driven production – Standardization

Requirement: Standardization

Reference-Architecture-Model Industrie 4.0 (RAMI 4.0)
- Three-tier system
- Joint development by: Bitkom, VDMA, ZVEI, Plattform Industrie 4.0

Standardization goals I4.0:
- Identification (location of participants)
- Semantics (communication)
- Quality of service (low latency, reliability)

→ compatibility and interoperability
3 Requirements for data-driven production – Industrial Data Space

Secure data exchange and data sovereignty: INDUSTRIAL DATA SPACE®

- **Insurance 4.0**
- **Retail 4.0**
- **Industrie 4.0**
  - Focus: manufacturing industry
  - Evolution
- **Banking 4.0**
- **Industrial Data Space**
  - Focus: Data
  - Disruptive Innovation

**Secure Data Exchange**

- **Industrie 4.0**
- Optimization: processes, market

**Smart Services**

- **New Products**
- **New Markets**
- **Data transmission Networks**
- **Real-time / low latency**
- **...**
Industrial Data Space

- Upload / Download / Search
- Internet
  - Apps
  - Vocabulary

- App Store

- Broker
  - Clearing
  - Index
  - Registry
- Industrial Data Space

- Internal IDS Connector
- External IDS Connector
- Third Party Cloud Provider

- Company A
- Company B

- Upload / Download
- Upload / Download / Search

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3 Requirements for data-driven production – Industrial Data Space
Industrial Data Space – Digital sovereignty for Industrie 4.0

Key data of the BMBF-Project
- Start: 1.10.2015

Highlights
- January 2016: Registered Association founded
- Round-table on EU-level
- CeBIT and Hannover Messe

Fraunhofer-Consortium
- 12 Institutes
- AISEC, FIT, FKIE, FOKUS, IAIS, IAO, IESE, IML, IOSB, IPA, ISST, SIT

Members of the Industrial Dataspace Association:
3 Requirements for data-driven production – Low latency communication

Requirement: Low latency for the tactile Internet

... as communication network with minimal signal delay

- Realized through e.g.: **5G**, **WiFi** and **wired** communication networks
- Enabling **new applications** in
  - **Industry** (as part of the industrial Internet: e.g. robotics)
  - **Mobility** (as part of the transport network. e.g. collaborative trial)
  - **Assistance** and **health** (Augmented Reality, Interactive learning)

Source: VDE-Positionspapier Taktiles Internet
3 Requirements for data-driven production – Low latency communication

Tactile Internet network architecture

**Use cases 5G:**
- Mobile high-speed Internet
- Car2Car & Car2X Communication
- Industrie 4.0

**Requirements:**
- 1000 x data throughput
- 100 x no. of devices
- 10 x battery life
- 1 ms latency

**System architecture for the mobile communication of the future (2019) via »Rainforest-Approach«**

**Providing coverage**
- Decimeter waves
  - FR: 300 MHz … 3 GHz
  - Radio communication, air traffic control, mobile phone
- Centimeter waves
  - FR: 3 … 30 GHz
  - Microwave link, satellite broadcasting, RFD
- Millimeter waves
  - FR: 30 … 300 GHz
  - »See-through walls«, ABS-cruise control, security scanner

HHI, IIS, FOKUS, AISEC
3 Requirements for data-driven production – Machine Learning

Machine Learning for optimized production processes

BIG DATA → SMART DATA → KNOWLEDGE → ADDED VALUE

- Training
- Deep Learning
- Complex Knowledge
- Reasoning
- Industrie 4.0
- Healthcare
- Logistics
- Smart Enterprise

Raw Data → Information → Decision → Productivity
3 Requirements for data-driven production – Machine Learning

»Machine Learning« leading to »Cognitive Machines«

Machine Learning (ML): »procedures of Artificial Intelligence that enable machines to learn from (data)examples in order to optimize their (decision) processes without being explicitly programmed.«

ML as enabler for »Cognitive Machines«

- Flexibility, versatility
- Interactivity, communication skills
- Iterativity, memory
- Contextual analysis, adaptability

Progress through »Moore’s Law«:
- processing speed
- data storage
- »clouds«
- »big data«
- fast internet
- miniaturization
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3 Requirements for data-driven production

4 Industrie 4.0 – examples of applied research
   ▪ Processes and connectivity
   ▪ Deep Learning in Manufacturing
   ▪ Smart logistics
   ▪ Human integration

5 Conclusion
The failure behavior of the component is compensated by mechanical calibration processes.

Behavior of components for calibration comes via protocol with the component.

Saving of Time and Costs of about 20%:
- Initial operation
- Maintenance
- Change of production
4 Fraunhofer R&D for Industrie 4.0 – Machine Learning

Process optimization with Machine Learning

Changes in material stress distribution during forming process

Data-based Machine Learning for predicting material stress distribution:

Data → Generic model → Status management → Adaptation for optimal action
BinGo: Drone-based Transport System

- Decentralized multi-agent system with advanced »ant colony« algorithm
- Energy-efficient and safe: Mainly rolling and only flying when necessary
- Battery charging while descending on rail-equipped spirals
Developing Industrie 4.0 competencies

Challenges:
Utilization of Industrie 4.0 applications for competence development and real-life learning environments

Requirements
- **Process understanding**, integration and **real-time synchronization** of processes throughout the product lifecycle
- **Transversal skills development** and training (IT, electronics, mechanics etc.)
- **Generic competences** about organization, communication and cooperation
- **High flexibility** and **decision-making** capability

Solutions for competence development: Fraunhofer »FUTURE WORK LAB«

Project work, simulations

Learning factories 4.0

Participation ramp-up
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4 Fraunhofer R&D for Industrie 4.0

5 Conclusion
4 Conclusion

Essentials for implementing Industry 4.0

- Latency and Data Rates: Tactile Internet, Intelligent Grids
- Security: Trusted Networks
- Compatibility: Standards
- Machine Learning: Process Optimization, Human collaboration
- Human Resources: ICT skills
Thanks for your attention

»Success is not final, failure is not fatal:
It is the courage that counts!«

Sir Winston Leonard Spencer-Churchill
(*30.11.1874; + 24.01.1965)