Towards the resilient factory

Insights from semiconductor production for "Industrie 4.0"

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Industry 4.0 and Cyber Physical Systems (CPS)

Semiconductor Manufacturing

- Standards
- Advanced Process Control (APC)
- From APC-enabled equipment to CPS

Summary and Outlook

Fraunhofer IISB

Fraunhofer IISB – Profile

Electronic Systems

From Materials to Power Electronic Applications –
Everything from One Source

Semiconductors • Power Electronics

Fraunhofer Institute for Integrated Systems and Device Technology (IISB) and Chair of Electron Devices (LEB)

LEB:
- 700 m^2 office and lab area
- 1000 m^2 cleanroom (ISO Cl 3/4)
- Staff: approx. 50

Fraunhofer IISB:
- 8390 m^2 office and lab area
- 525 m^2 cleanroom (ISO Cl 3)
- Staff: approx. 290
- Subsidiaries:

Center for Automotive Power Electronics and Mechatronics ZKLM, Nuremberg

Technology Center for Semiconductor Materials THM, Freiberg (Saxony)

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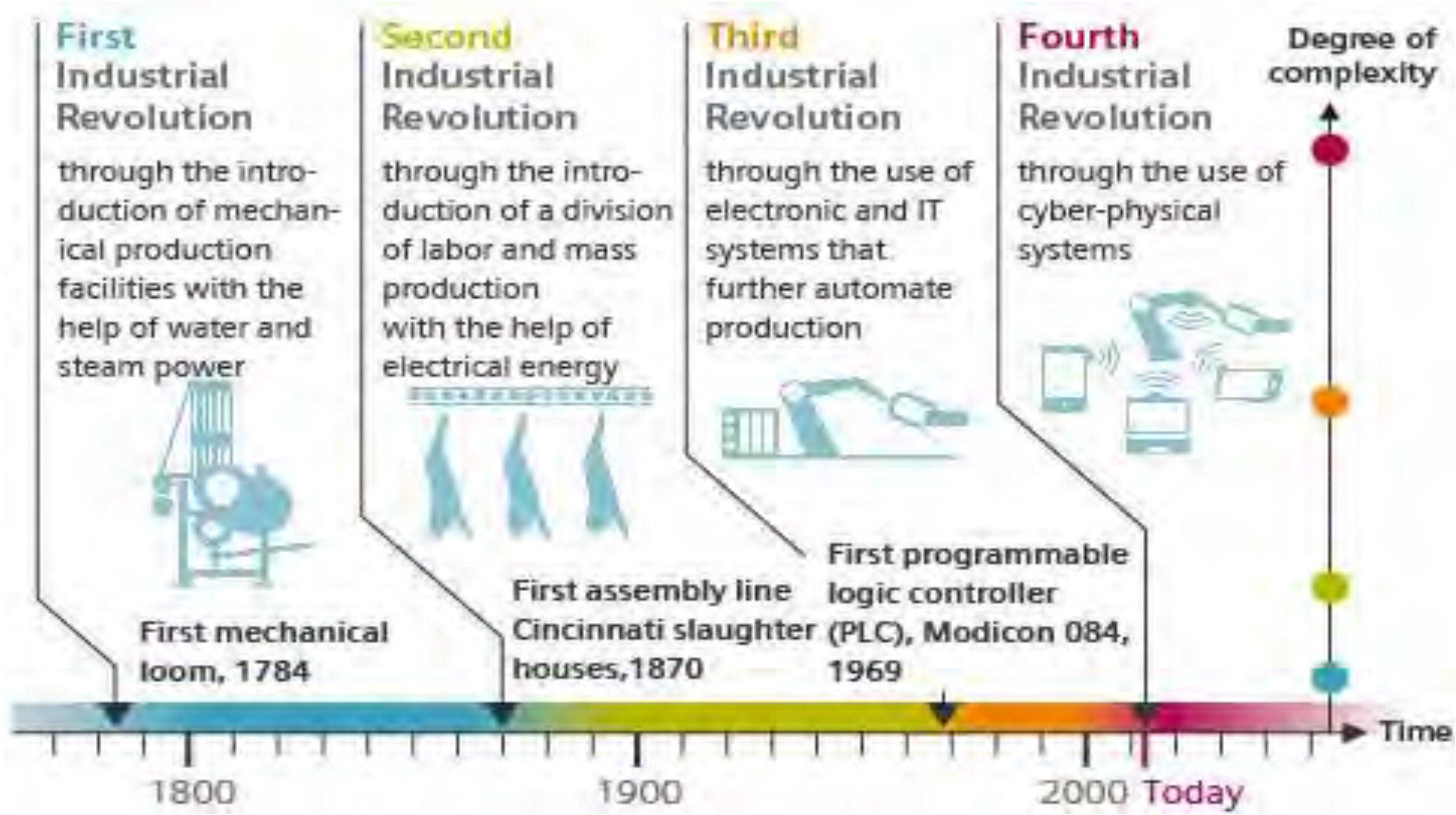
Industry 4.0

History



Source: DFKI (2011), siemens.com

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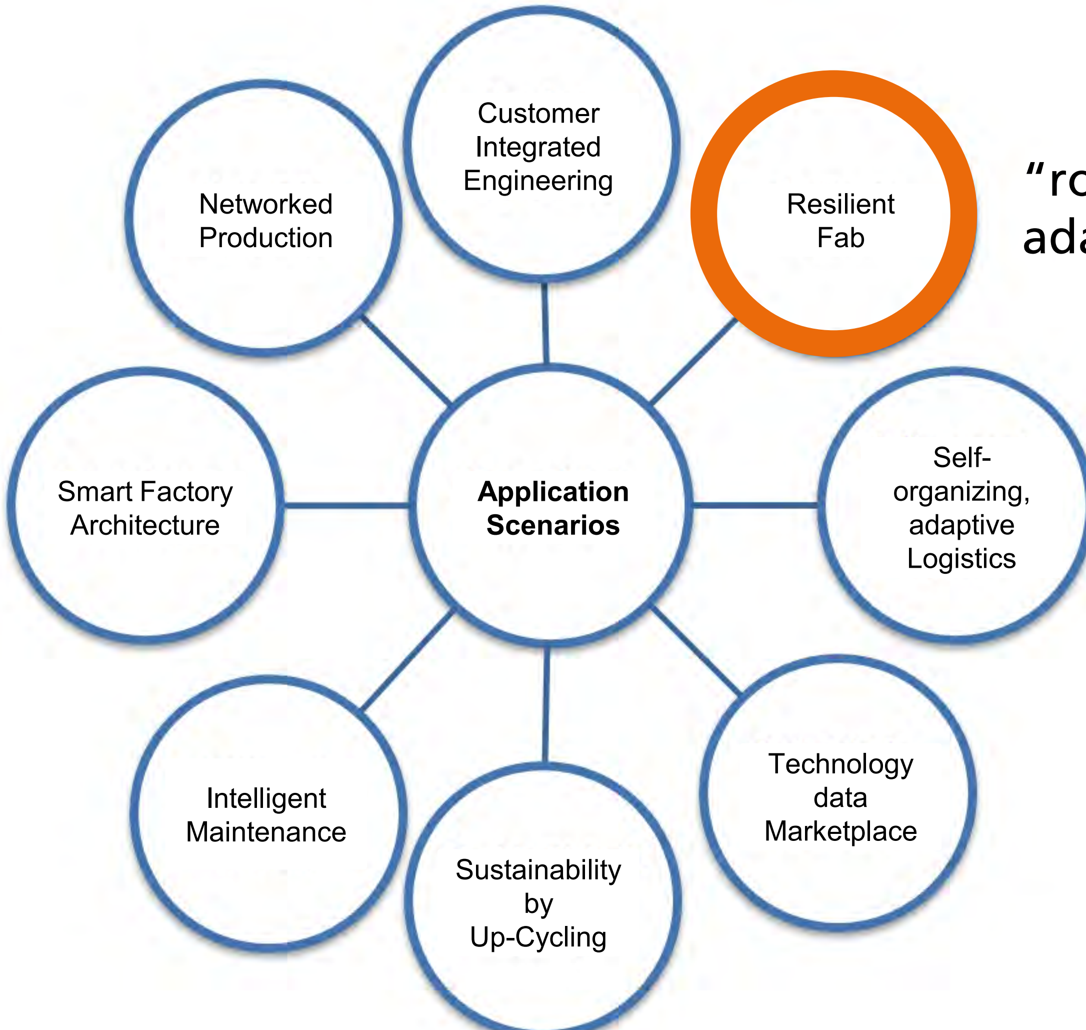
Industry 4.0

Application Scenarios



"robustness and adaptability"

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Industry 4.0

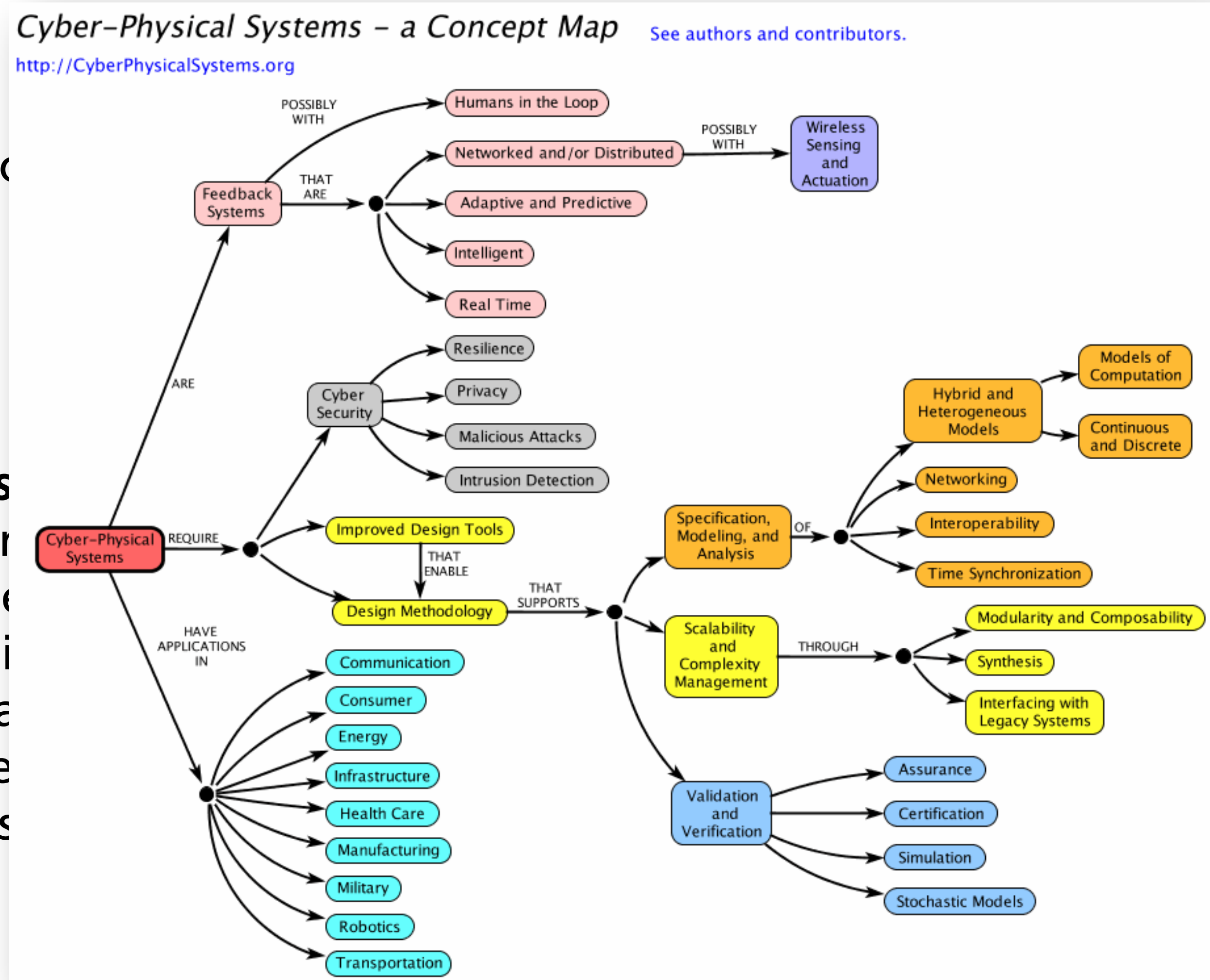
Cyber Physical Systems

Apparently: CPS is a fo

… **what is a CPS?**

Wikipedia:

A **cyber-physical sys**
elements controllir
cyber-physical syste
automotive, chemi
manufacturing, tra
appliances. This ge
embedded systems
elements, and less
physical elements.



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Industry 4.0

Many Open Questions

"… 85% of the experts are convinced that most German companies have no clear understanding of Industry 4.0"

Pressemeldungen | 06.08.2014

eco: Wirtschaft ohne Orientierung bei Industrie 4.0

Dr. Bettina Horster: „Viele Unternehmen sind mit Industrie 4.0 schlichtweg überfordert"

Der Umgang der deutschen Wirtschaft mit Industrie 4.0 ist weitgehend durch Orientierungslosigkeit und Überforderung geprägt. Dies ist die Kernaussage einer aktuellen Expertenumfrage von eco – Verband der deutschen Internetwirtschaft e. V. 85 Prozent der von eco befragten Fachleute sind der festen Überzeugung, dass die meisten Unternehmen in Deutschland keine klare Vorstellung davon haben, was Industrie 4.0 eigentlich ist und wie sie aussehen wird. 94 Prozent der Experten halten die deutsche Wirtschaft durch die für Industrie 4.0 erforderliche Zusammenschaltung von Hardware, Software und Telekommunikation für schlichtweg überfordert.

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Industry 4.0

Many Open Questions

"32% of the managers claim that they have not yet heard or read about Industry 4.0"

07.04.2015

Jedem dritten Produktionsbetrieb ist Industrie 4.0 kein Begriff

- Umfrage unter Führungskräften in den industriellen Kernbranchen
- Aussteller zeigen die vernetzte Produktion in der „Bitkom Innovation Area Industrie 4.0“ auf der Hannover Messe
- 45 Vorträge und 10 Podiumsdiskussionen beim „Forum Industrie 4.0“

Berlin, 7. April 2015 - Industrie 4.0 ist in Medien, Politik und Wirtschaft hochaktuell und auf der diesjährigen Hannover Messe das bestimmende Thema. Dennoch ist der Begriff in deutschen Fertigungsunternehmen noch nicht hinlänglich bekannt. Das zeigt eine Umfrage im Auftrag des Digitalverbands Bitkom. Demnach sagen die Führungskräfte von gut jedem dritten Unternehmen (32 Prozent) aus der Automobilbranche, dem Maschinenbau, der chemischen Industrie sowie der Elektroindustrie, dass sie bislang noch nichts über Industrie 4.0 gehört oder gelesen haben. Befragt wurden je Branche 100 Unternehmen mit mindestens 100 Mitarbeitern. „Angesichts der hohen Bedeutung von Industrie 4.0 macht dieses Ergebnis nachdenklich“, sagt Winfried Holz, Mitglied des Bitkom-Präsidiums. „Die Zukunft der einzelnen Branchen und des Wirtschaftsstandorts Deutschland hängt entscheidend davon ab, wie zügig und gut es gelingt, die klassische Produktion zu digitalisieren und neue Geschäftsmodelle zu entwickeln. Wer sich jetzt nicht mit dem Thema auseinandersetzt, könnte den Anschluss verpassen.“

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Industry 4.0 and Cyber Physical Systems (CPS)

Semiconductor Manufacturing

- Standards
- Advanced Process Control (APC)
- From APC-enabled equipment to CPS

Summary and Outlook

Semiconductor Manufacturing

… what comes to mind

Sources: fintacts.ie, computer-oiger.de, xbitlabs.com, de.wikipedia.org, dailytech.com

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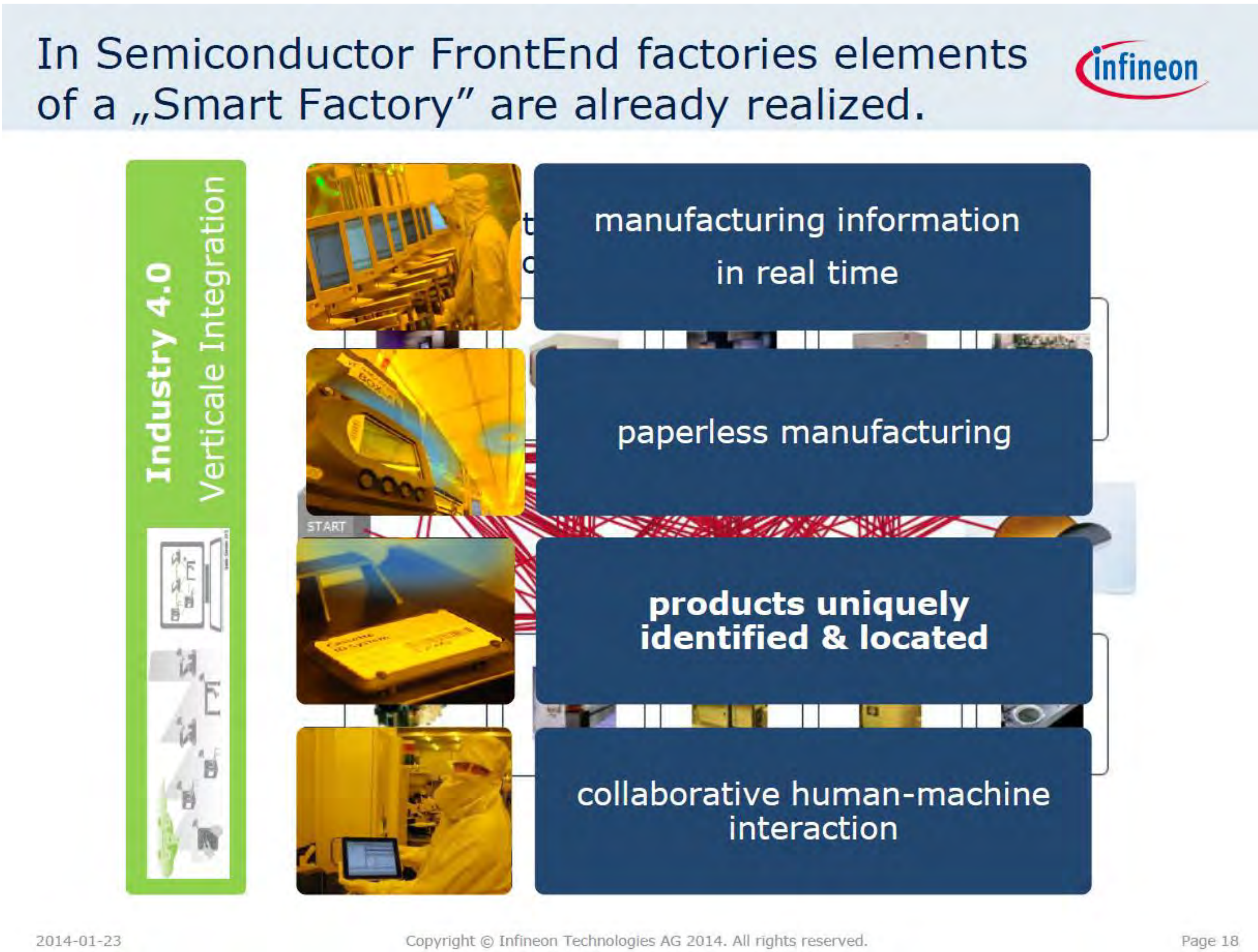
Semiconductor Manufacturing

A semiconductor view on "Industry 4.0"



Dr. T. Kaufmann, Infineon

11th Innovationsforum for automation, 2014, Dresden

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Industry 4.0 and Cyber Physical Systems (CPS)

Semiconductor Manufacturing

- **Standards**
- Advanced Process Control (APC)
- From APC-enabled equipment to CPS

Summary and Outlook

Standards

Some history

Most famous standard: „SECS/GEM“

- 1978: Hewlett-Packard proposed that standards be established for communications among semiconductor manufacturing equipment.
- 1980/1982: SEMI published the SECS-1/SECS-II standards
- 1992: GEM standard published
- Continued: HSMS, GEM300, EDA/Interface A, …

semi

„Semiconductor Equipment and Materials International“

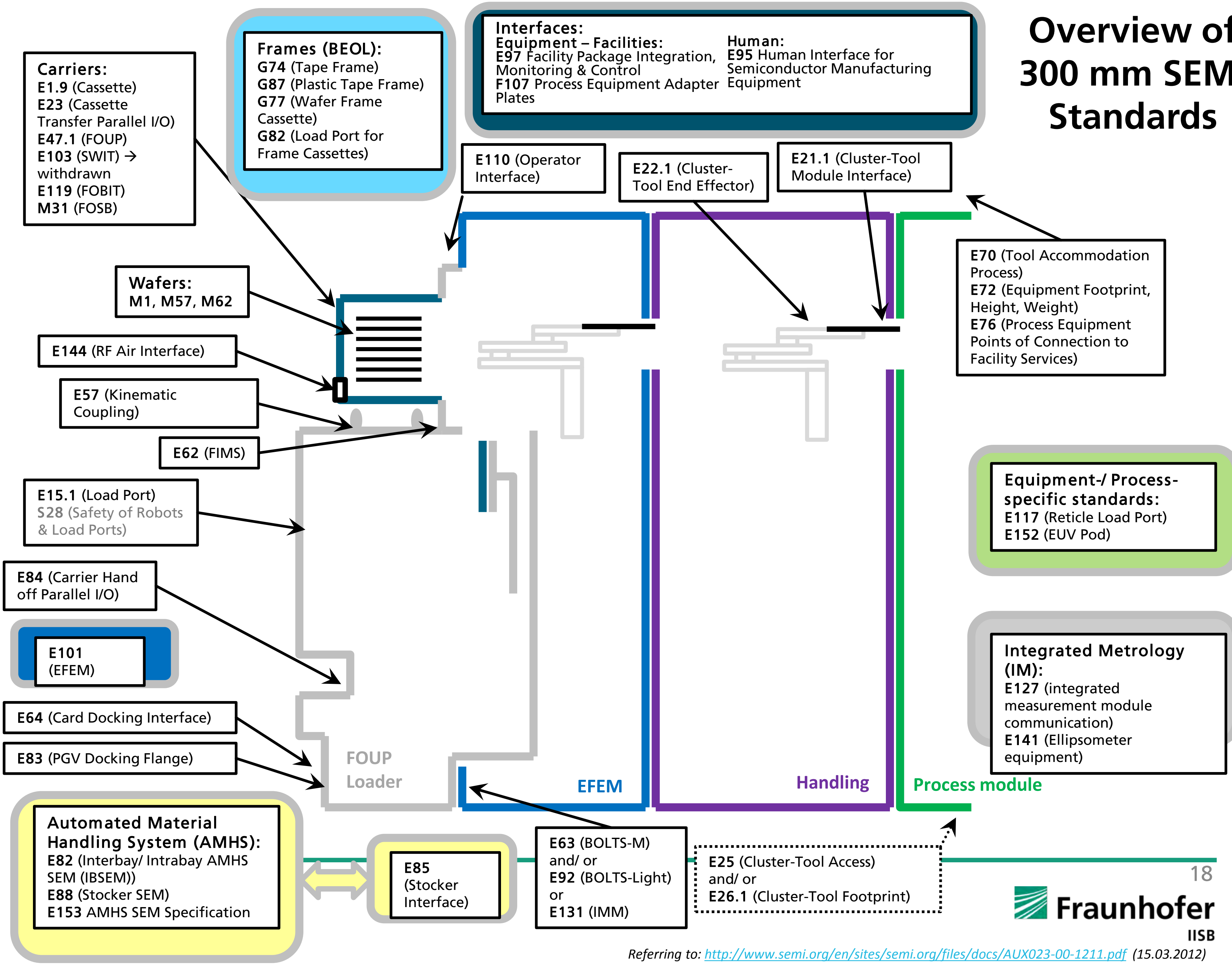
- Founded in 1970
- Tradeshows (SEMICON), conferences, networking
- **Industry standards** (> 800 standards and safety guidelines)
- USA - Japan - Europa - Taiwan - Korea - China
- www.semi.org

GEM
- Defines equipment behavior

SECS II
- Data items, messages

SECS 1
- Electrics/mechanics, transactions

Overview of 300 mm SEMI Standards



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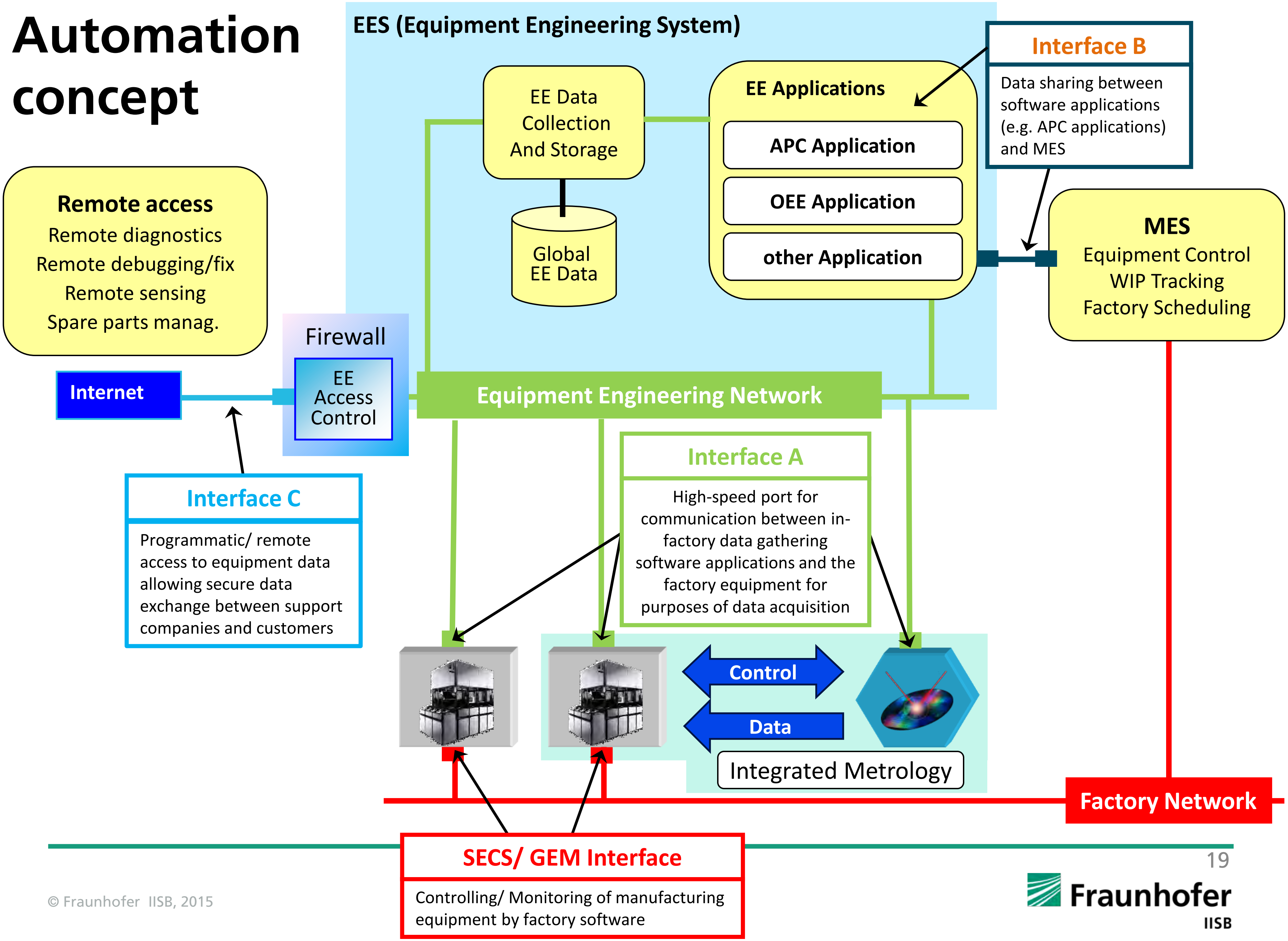
Referring to: http://www.semi.org/en/sites/semi.org/files/docs/AUX023-00-1211.pdf (15.03.2012)

Automation concept



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Industry 4.0 and Cyber Physical Systems (CPS)

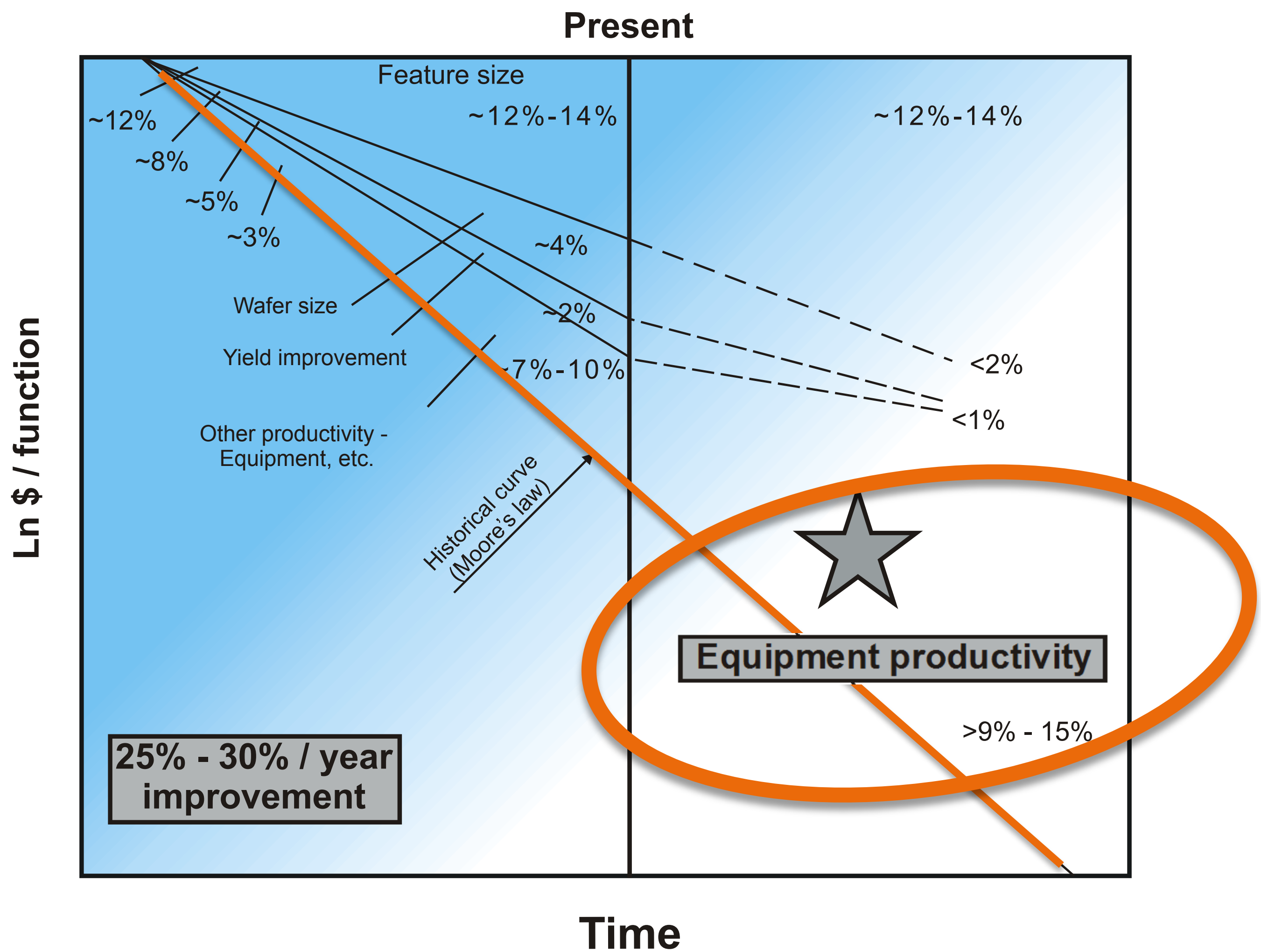
Semiconductor Manufacturing

- Standards
- **Advanced Process Control (APC)**
- From APC-enabled equipment to CPS

Summary and Outlook

APC in semiconductor manufacturing

The productivity gap



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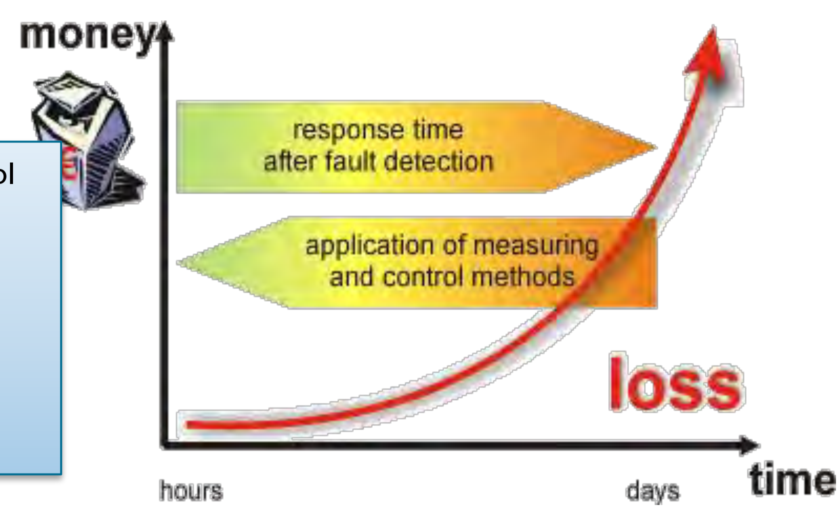
APC in semiconductor manufacturing

„Big data" and Advanced Process Control

- Objective: Ensure high productivity and product quality
- Fundamental goals of APC ("Advanced Process Control")
  - to apply measures for process control close to the process
  - to automate control actions
- Typical APC methods (SEMI E133):
  - SPC, FDC, FP, RtR, VM, PdM
- Basis for APC:
  - Metrology data
  - Data from equipment & processes
  - Logistics data

Statistical Process Control
Fault Detection and Classification
Fault Prediction
Run-to-Run Control
Virtual Metrology
Predictive Maintenance



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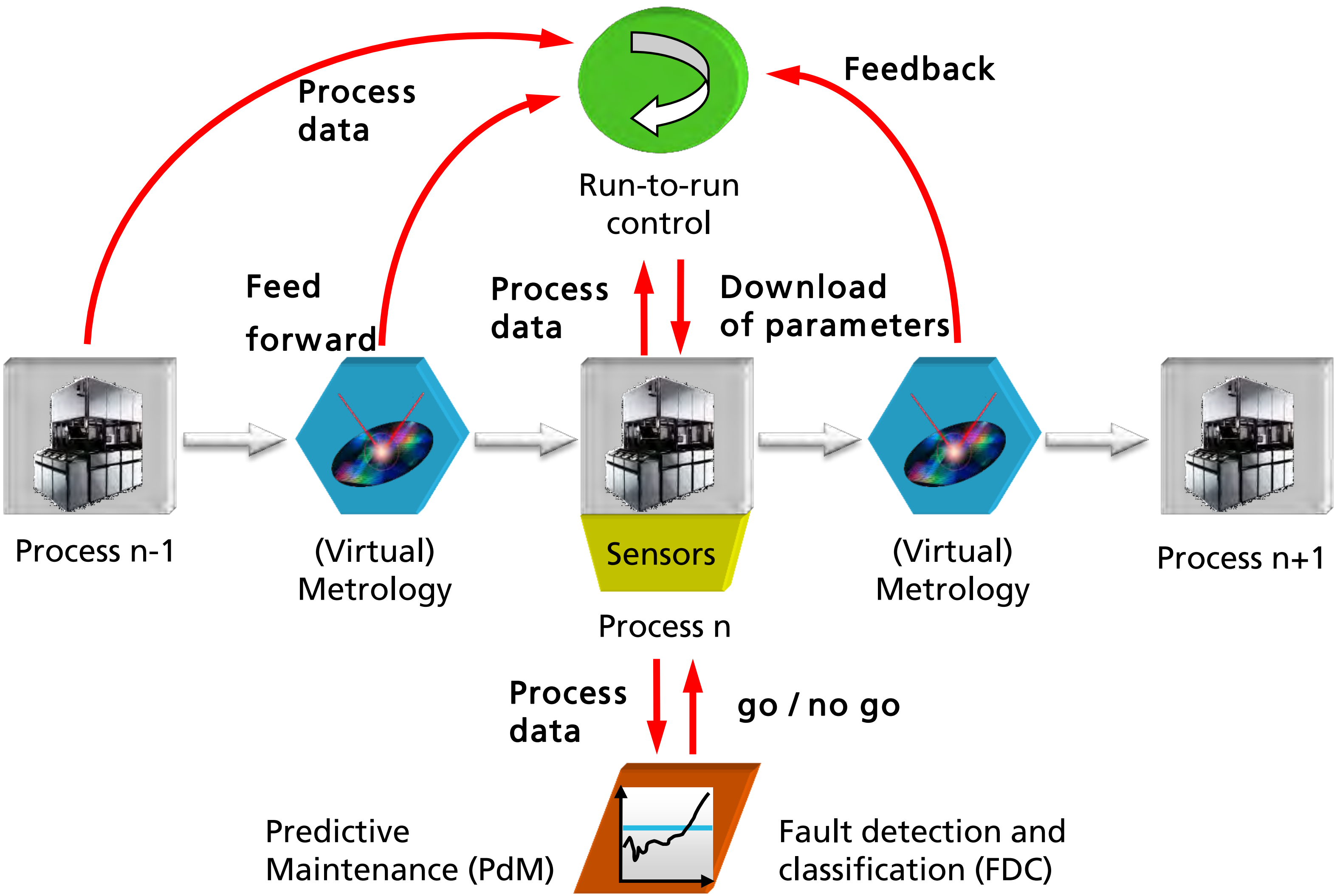
APC in semiconductor manufacturing

Interaction of APC elements



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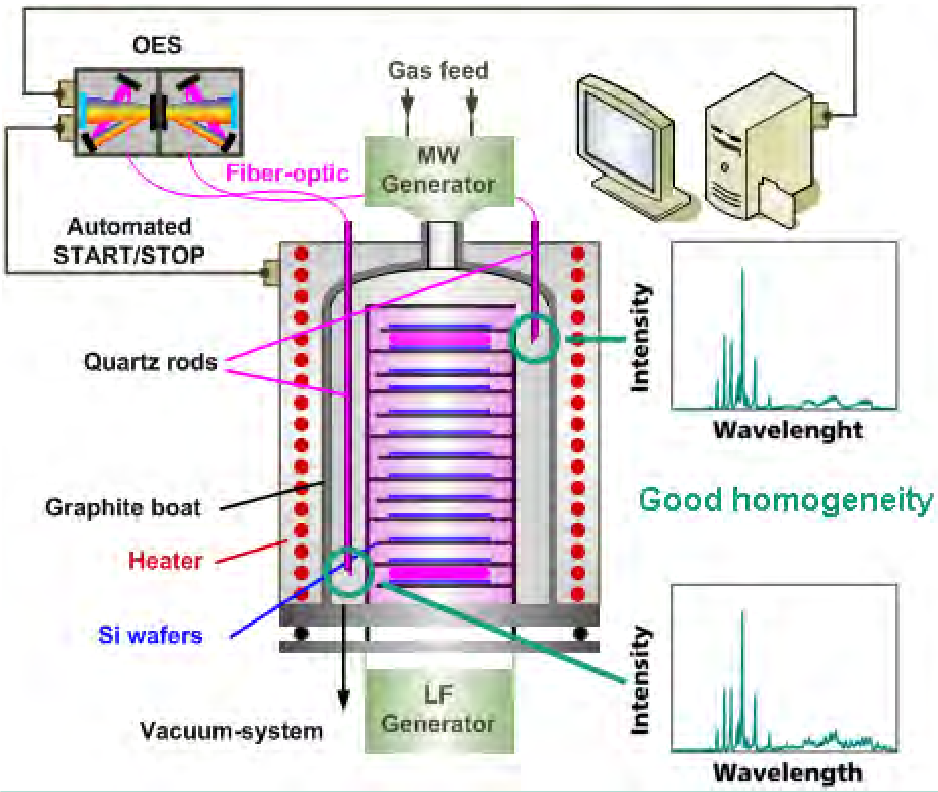
APC in semiconductor manufacturing

Examples for productivity enhancement by APC

Real-time control of plasma processes by integrated OES

Higher productivity at equipment level



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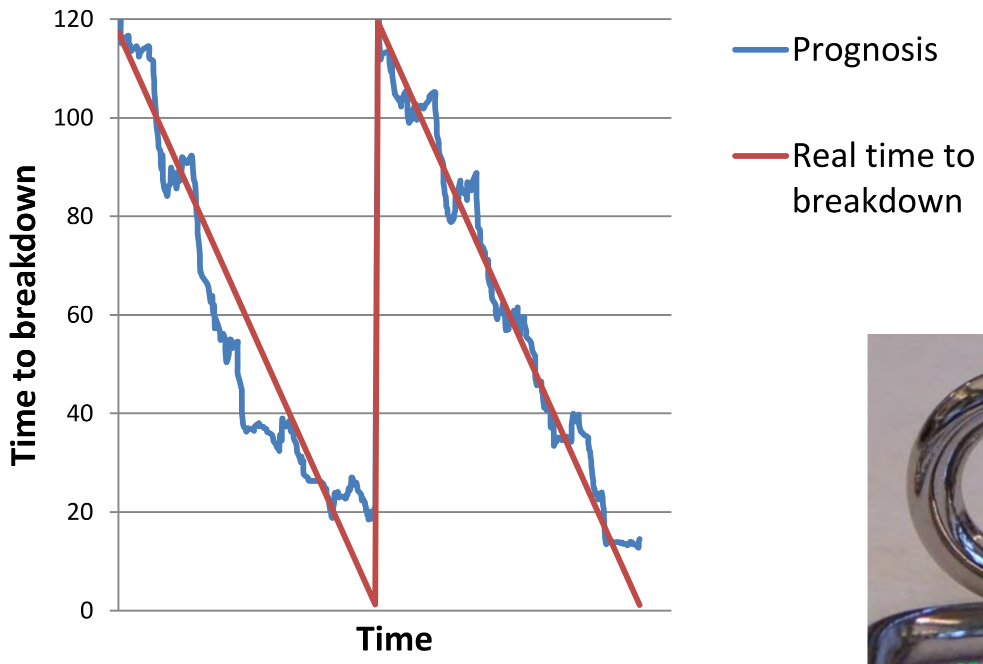
APC in semiconductor manufacturing

Examples for productivity enhancement by APC

Prediction of maintenance events by PdM

Optimized tool operation and maintenance planning



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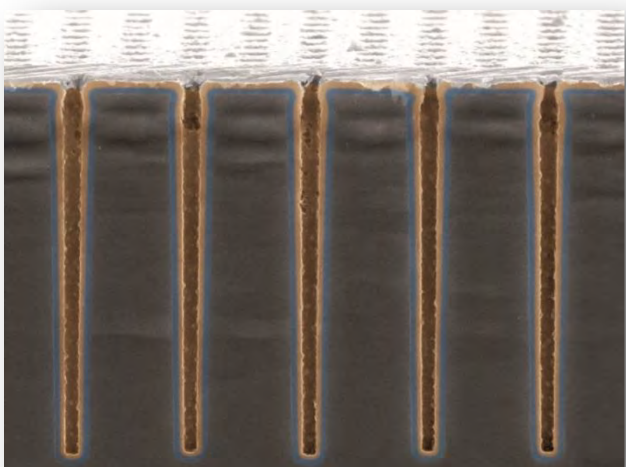
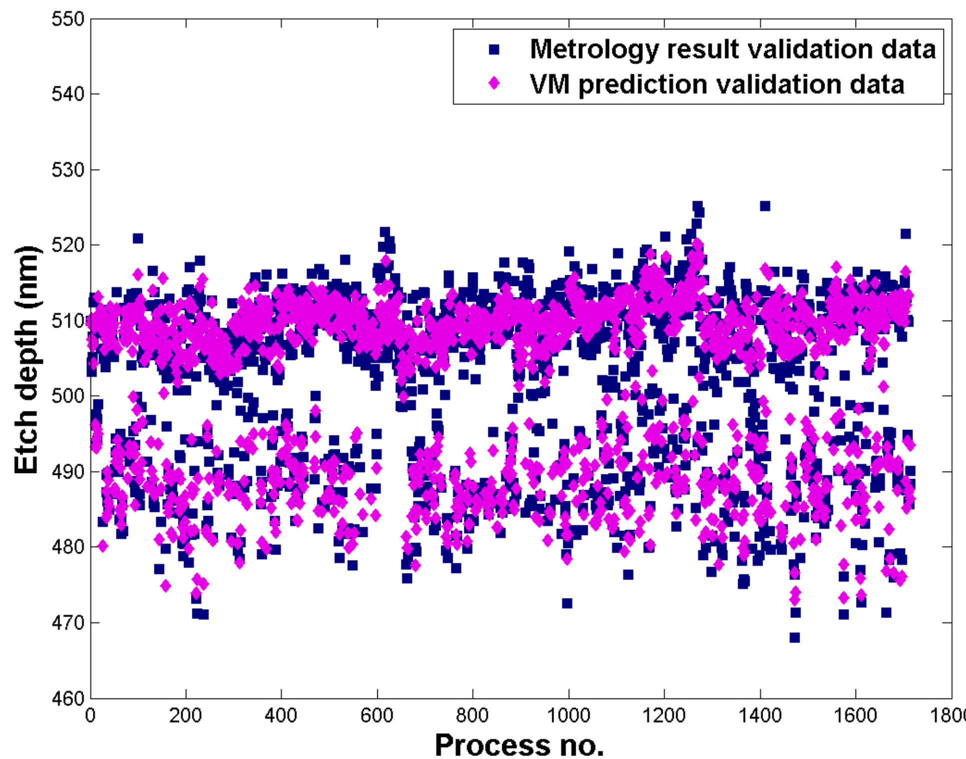
APC in semiconductor manufacturing

Examples for productivity enhancement by APC

Prediction of quality parameters by virtual metrology

Tight process control by "measuring" every wafer





Prediction of etch depth by VM - predicted data vs. metrology results

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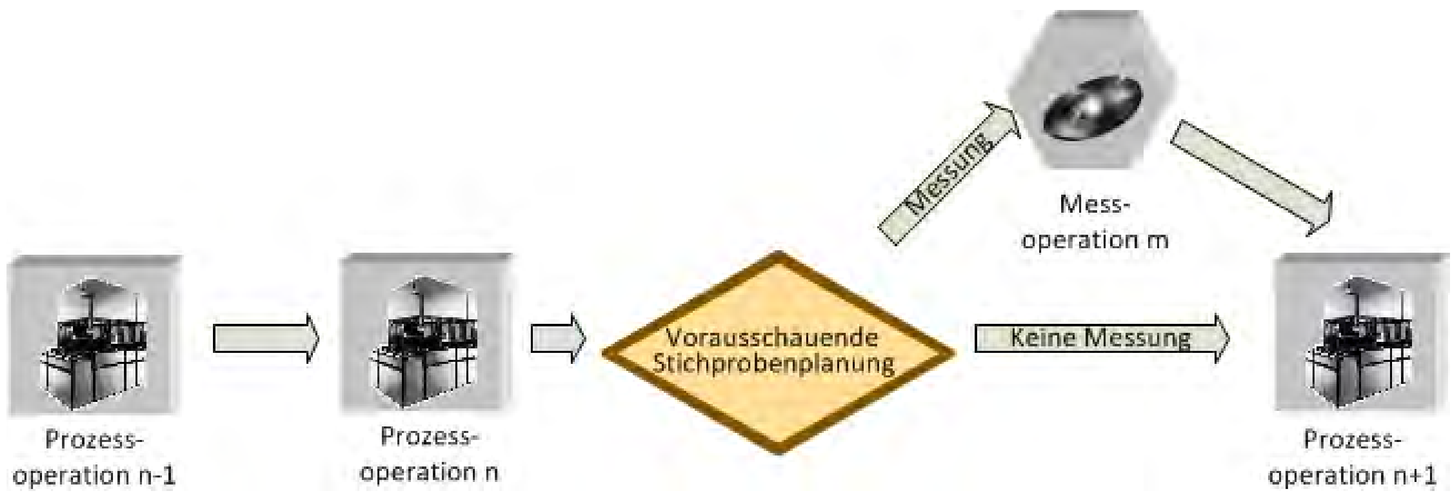
APC in semiconductor manufacturing

Examples for productivity enhancement by APC

Flexible sampling and predictive scheduling with W@R* indicator

Best quality control with minimized number of measurements



* Wafers at risk = amount of uncontrolled wafers

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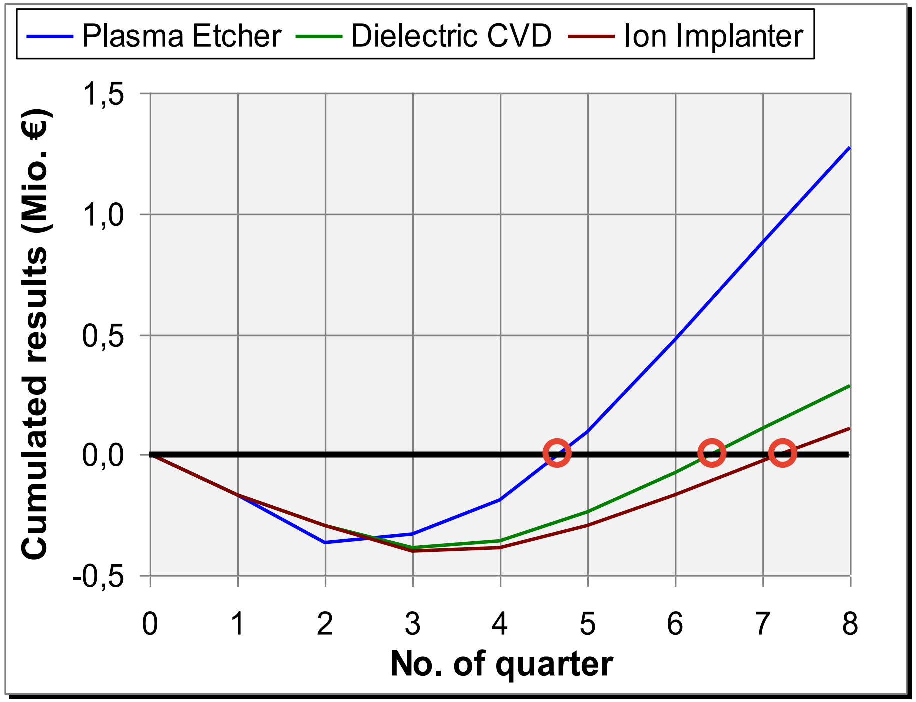
APC in semiconductor manufacturing

Estimation of benefits – RoI

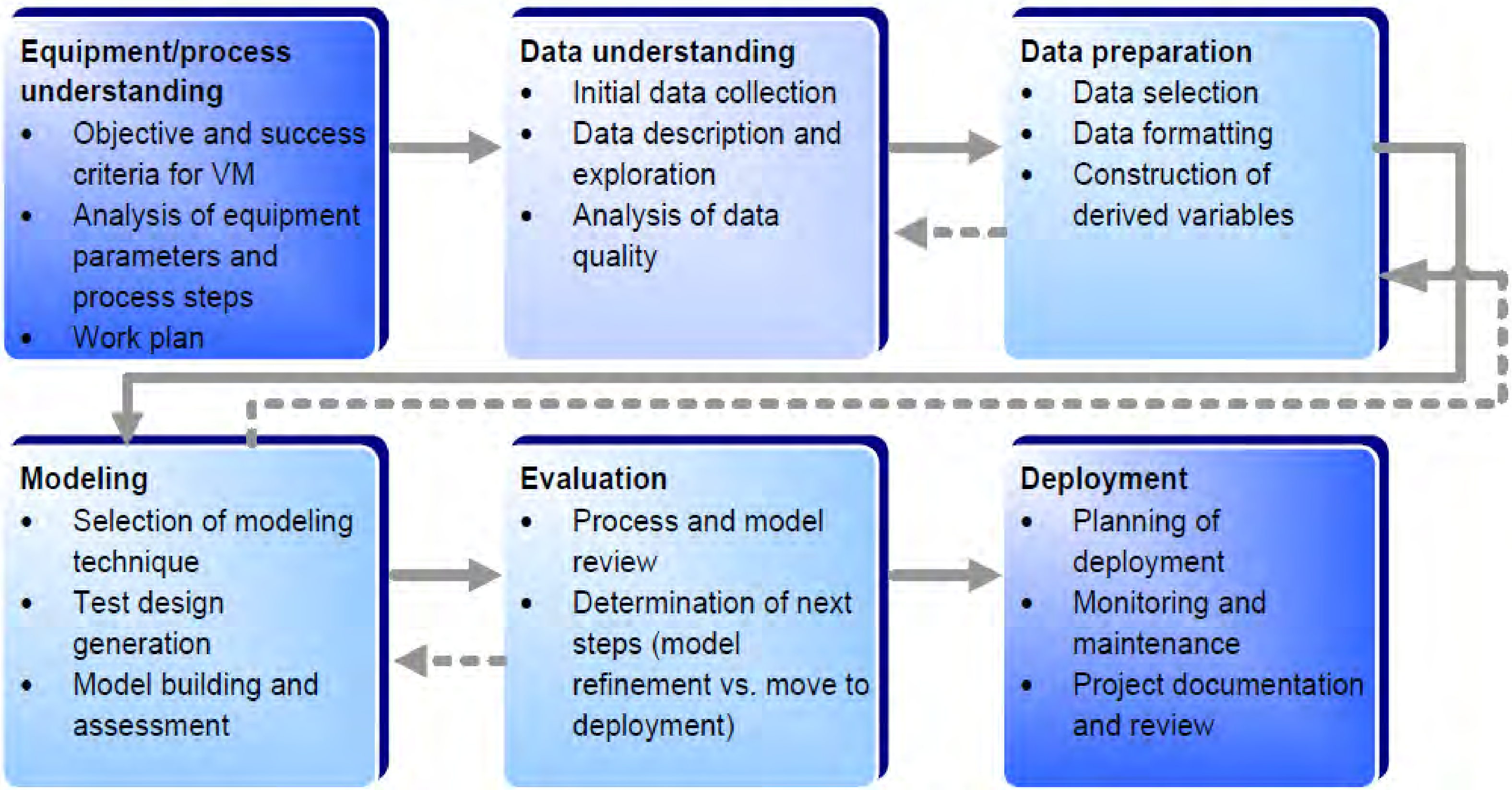
- Investment assessment for APC in semiconductor manufacturing
- Identification of economic effects from APC – possible savings and cost
- Development of models to calculate economical figures of merit, e.g., RoI, payback period
- FMEA to identify and quantify new risks from the introduction of APC



APC in semiconductor manufacturing

Structured approach for development and deployment

Phases in VM/PdM development as adapted from the Cross-Industry Standard Process for Data-Mining (CRISP-DM)



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- **From APC-enabled equipment to CPS**

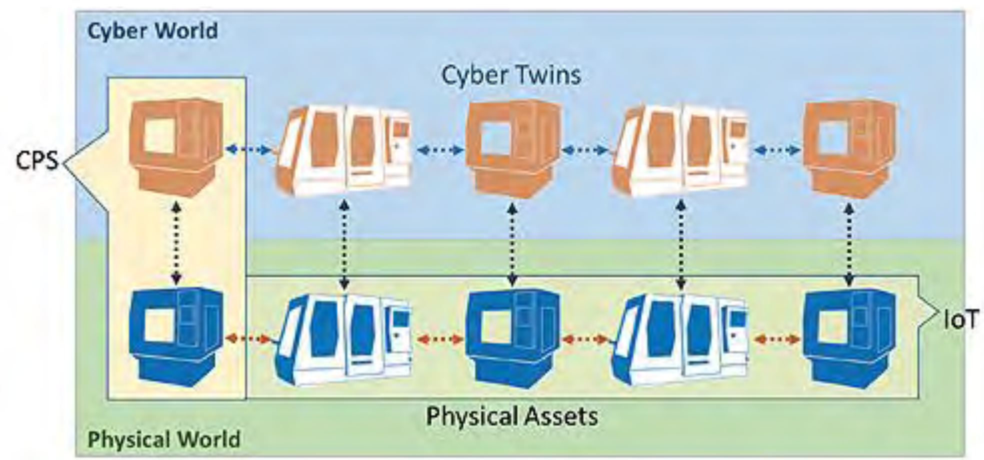
Summary and Outlook

From APC-enabled equipment to CPS

Cyber Physical Systems – basis for the resilient fab

Properties of a Cyber Physical System

- CPS are based on connectivity (IoT)
- CPS run complex analytics
- CPS extract knowledge from raw data



A cyber-physical system is characterized by a physical asset, such as a machine, and its digital twin; basically a software model that mimics the behavior of the physical asset. In contrast, the IoT in common parlance is generally limited to the physical assets, not their digital models.

http://www.designworldonline.com/big-future-for-cyber-physical-manufacturing-systems/#_

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From APC-enabled equipment to CPS

Cyber Physical Systems – basis for the resilient fab

Data collection from various sources (internal, external)

„Self"-Perception

Perception of environment

Control of physical assets

According action/ re-action

INTERNAL

Communication

EXTERNAL

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Summary and Outlook

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Summary & Outlook

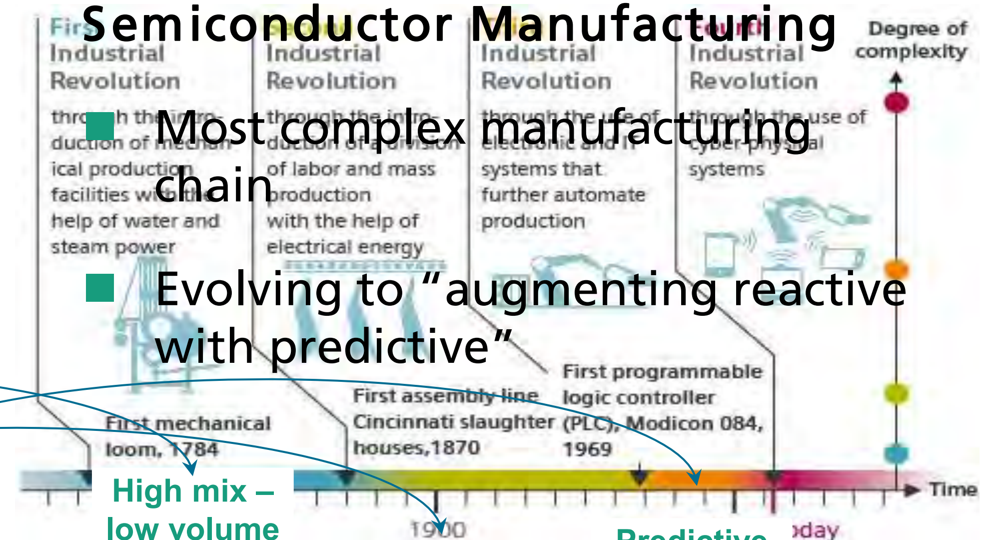
The chance of working together

„Industry 4.0“

- Mostly linear production processes
- Combine physical objects with “intelligence” → “cyber-physical systems”

Semiconductor Manufacturing

- Most complex manufacturing chain
- Evolving to “augmenting reactive with predictive”



Custom Tailored Production

Resilient Fab

Self-organizing, adaptive Logistics

Smart Factory Architecture

Intelligent Maintenance

High mix – low volume

Process Control Systems

Predictive Scheduling

Smart Fab

Predictive Maintenance

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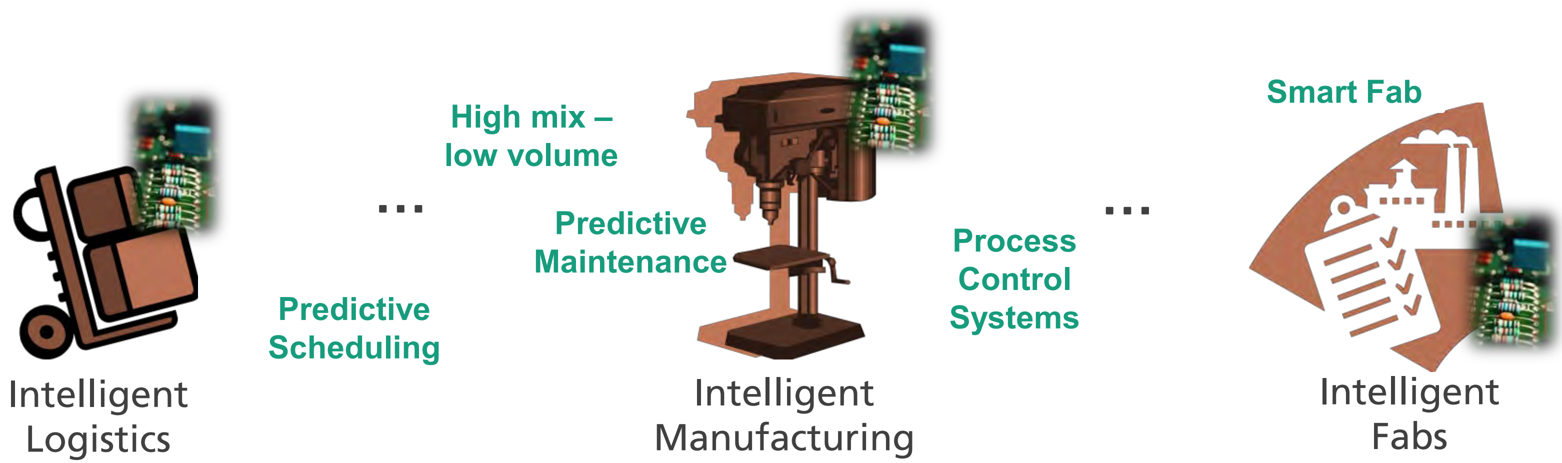
Summary & Outlook

The chance of working together

Mission of Fraunhofer IISB

- Merge “Industry 4.0” trend with “augmenting reactive with predictive” trend
- From “APC-enhanced equipment” to “cyber-physical systems”



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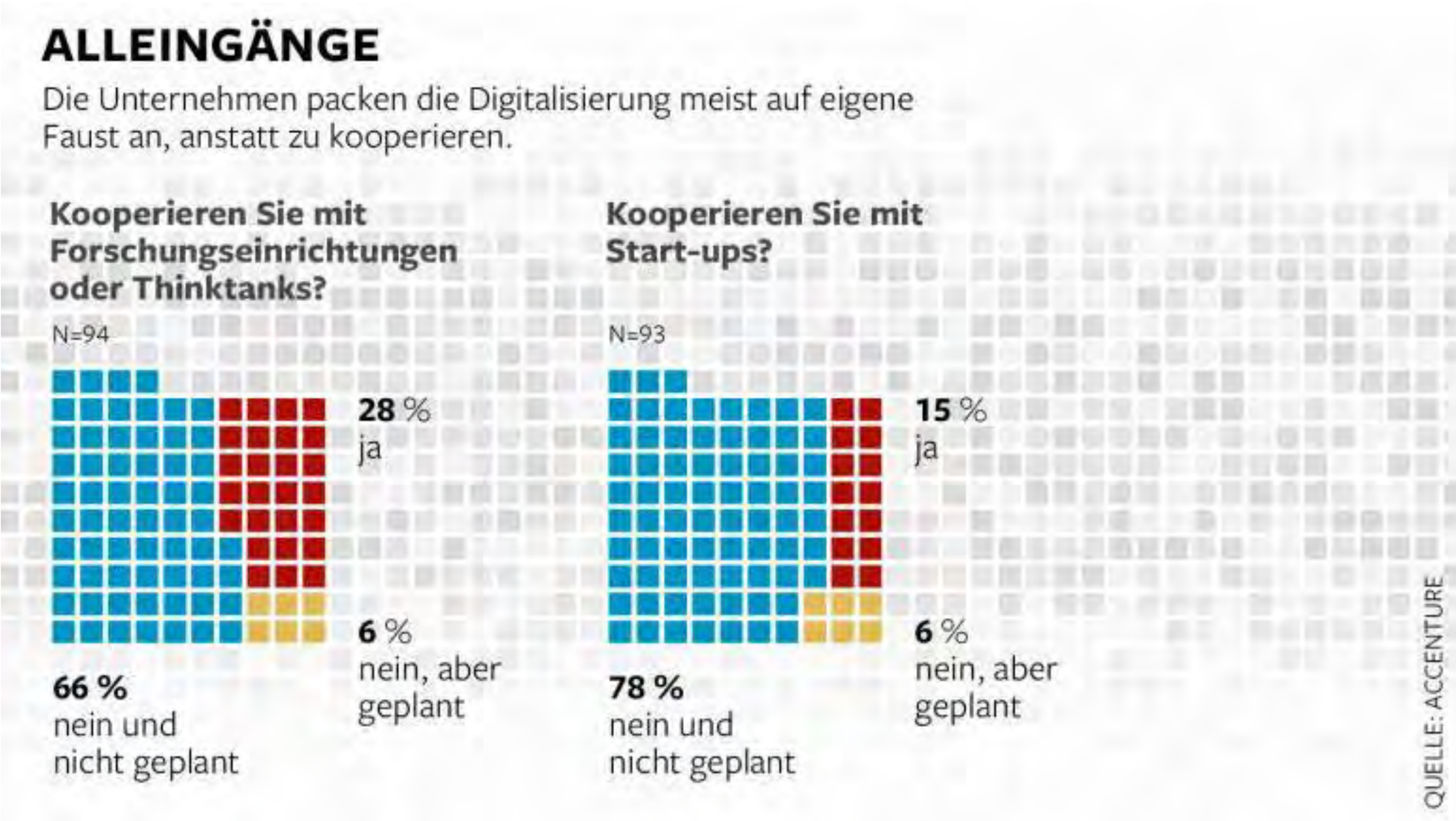
Summary & Outlook

The chance of working together



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Summary & Outlook

The chance of working together

Lessons learned from APC in semiconductor manufacturing

1. Collaborate (competitors, universities, …)
2. Know your process
3. Make use of standards
4. Good to have data from
   >1 year of production
5. Take care of data quality
6. Combine knowledge of
   data experts and process experts
7. Go for low-hanging fruits …
8. … but avoid "island-solutions"
9. Collaborate

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Summary & Outlook

The chance of working together

Achievements in semiconductor manufacturing

- Standards and automation concepts evolved over more than 35 years
- Proven as basis for improving productivity

Potential for other industries

- "Hold on to what is good" – knowledge and definitions
- Well experienced R&D and suppliers available

The chance of working together

- From APC-enhanced equipment to cyber-physical systems
- Semiconductor manufacturing: strategic partnerships with other industries, spearheading with products and "manufacturing science"

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- the EU projects SEA-NET and SEAL.

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Thanks

for your attention!

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