Predictive Maintenance:
Lessons learned from Semiconductor Manufacturing

MAPEtronica – Conference about Industry 4.0
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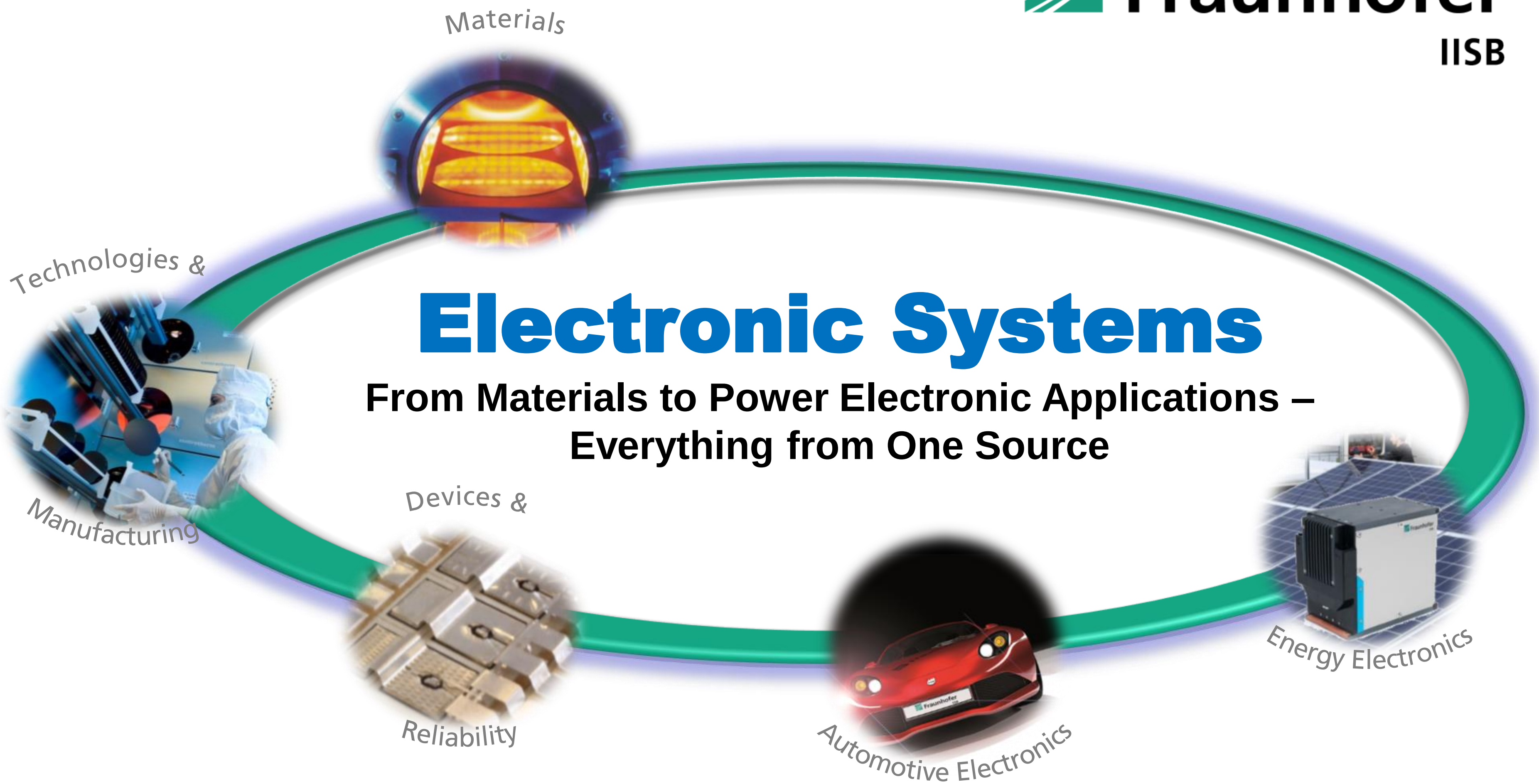
Electronic Systems

From Materials to Power Electronic Applications – Everything from One Source



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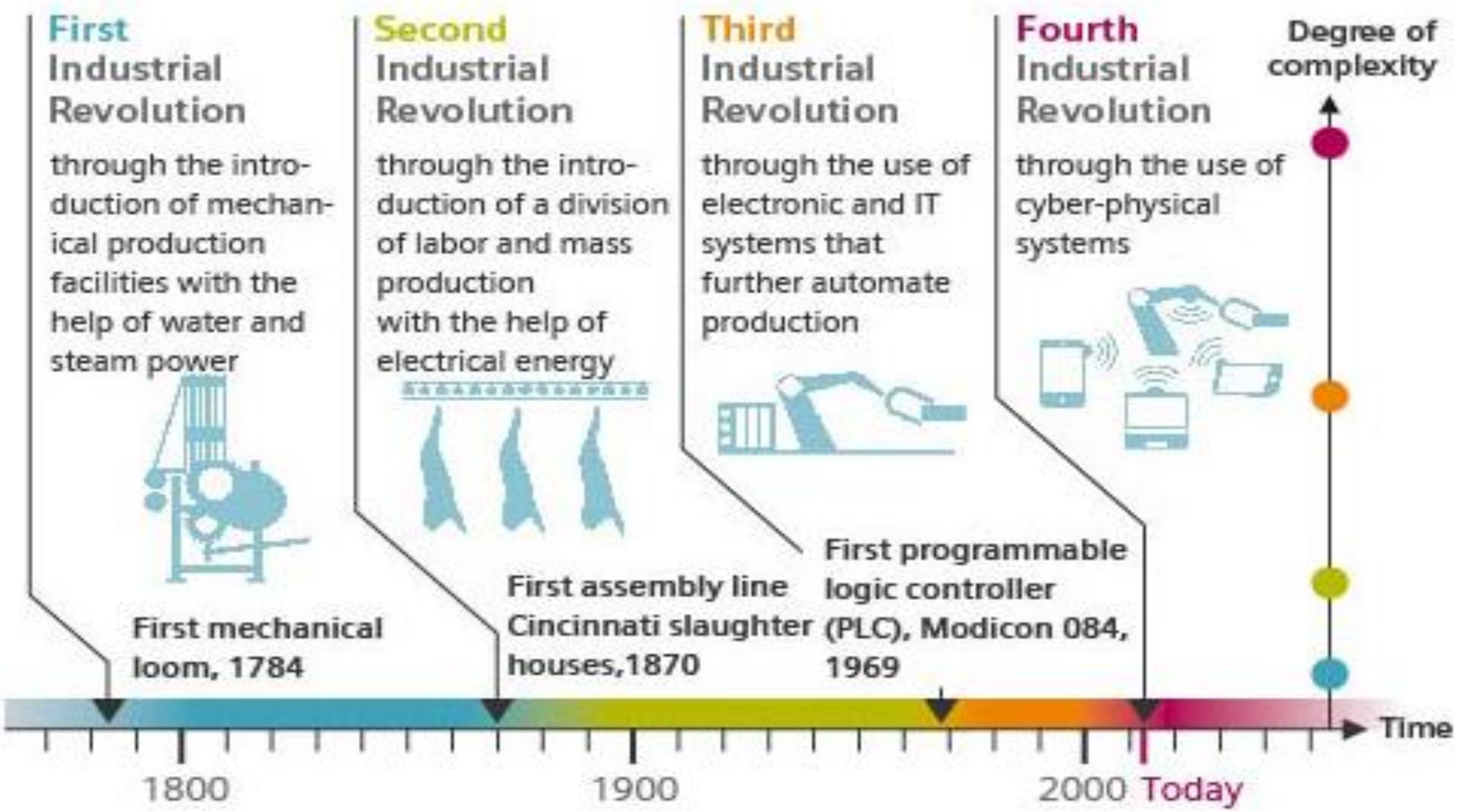
Industry 4.0

History



Source: DFKI (2011), siemens.com

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Industry 4.0

Fraunhofer Layer Model of Industry 4.0 Value Creation

- **Three Layers**
  - Production
  - ICT
  - Enterprise Transformation
- More than **150 topics**
- Driven by **experts from 20 institutes**
- Knowhow based on **more than 300 projects**

http://www.academy.fraunhofer.de/

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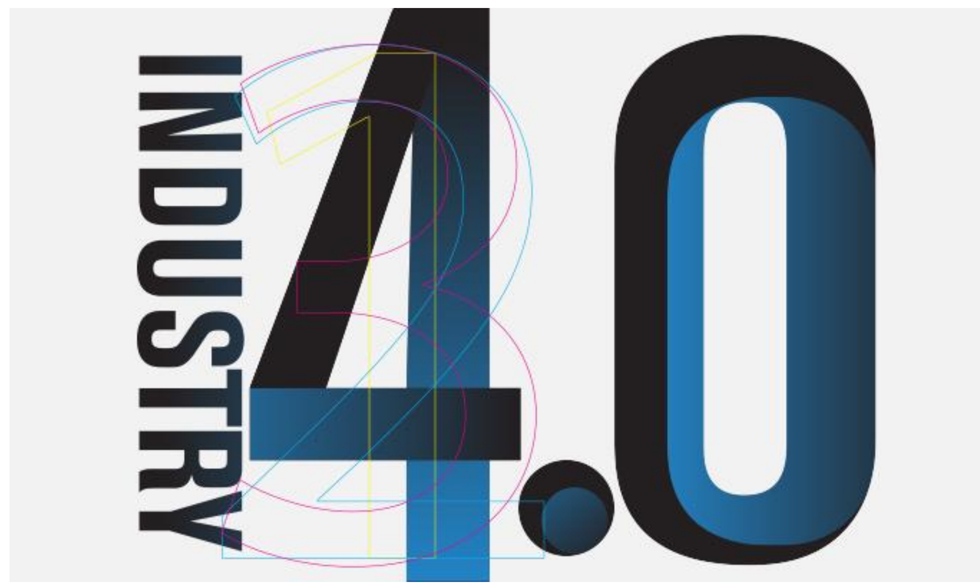
Agenda

1. Industry 4.0 in Semiconductor Manufacturing

2. Dr. Production, Predictive Maintenance and Beyond

3. Outlook



www.strategy-business.com

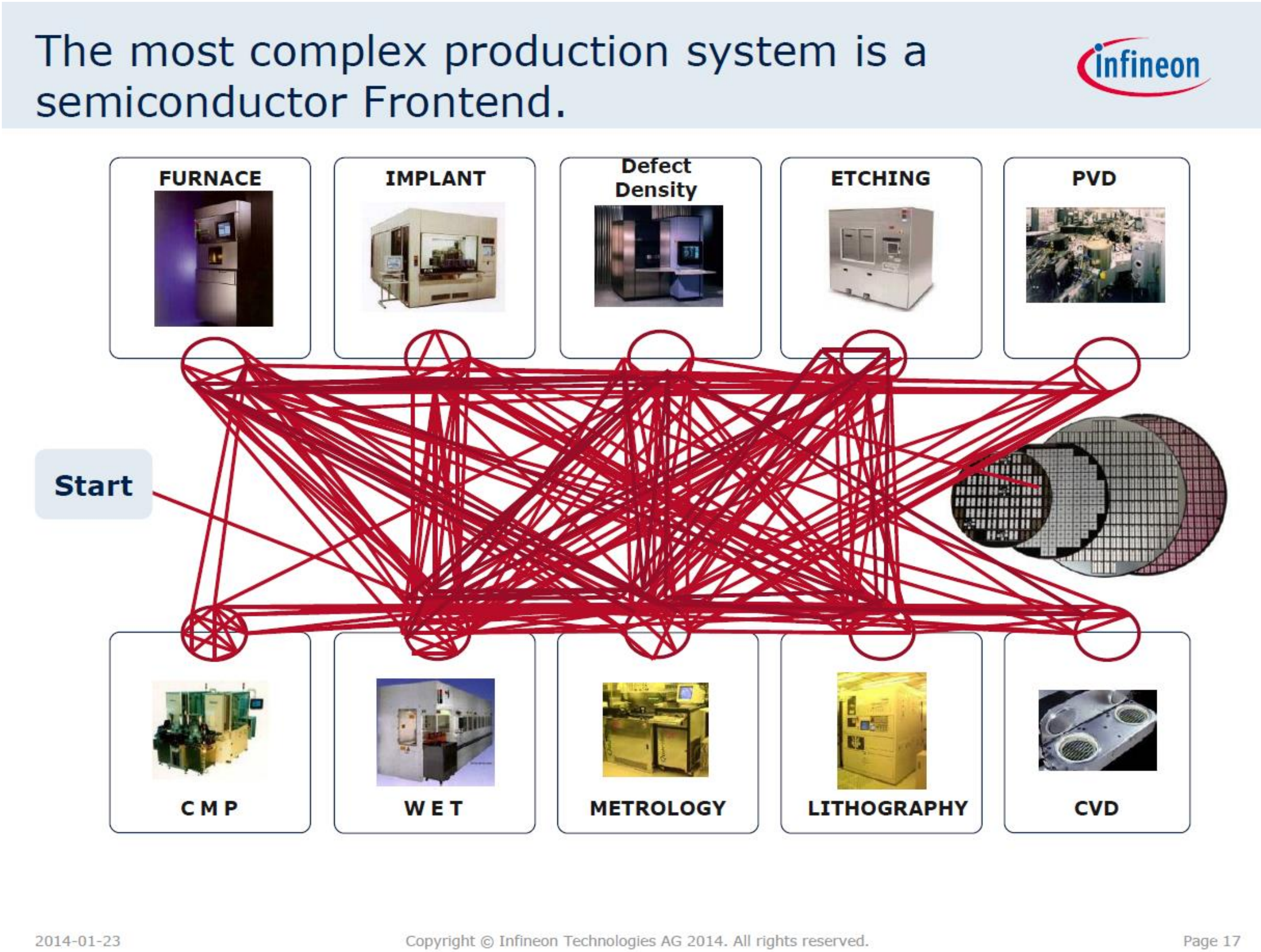
Semiconductor Manufacturing

… what comes to mind

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

Semiconductor Manufacturing

A semiconductor view on "Industry 4.0"



Dr. T. Kaufmann, Infineon

11th Innovationsforum for automation, 2014, Dresden

Semiconductor Manufacturing

Some history on standards

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

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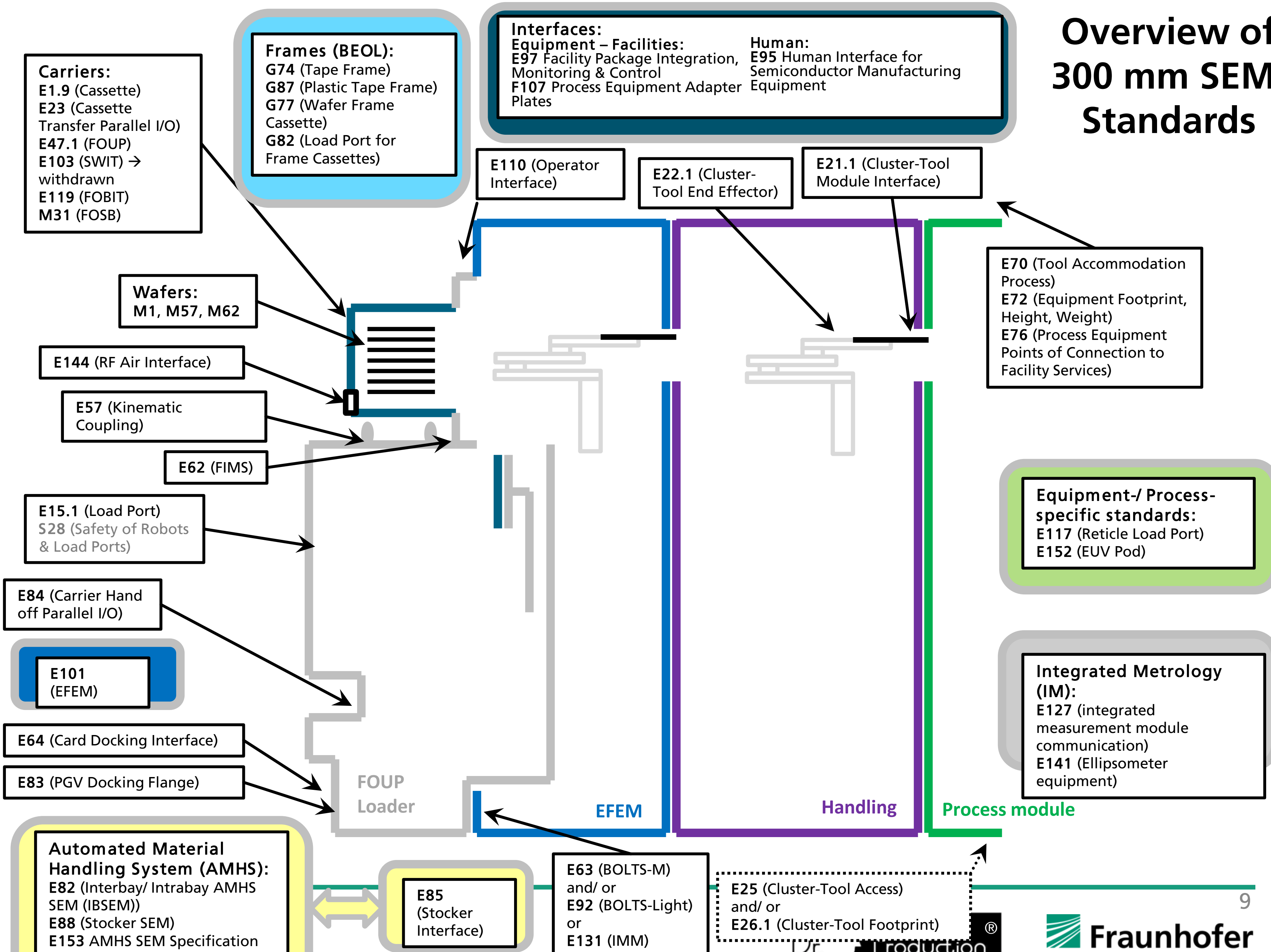
Overview of 300 mm SEMI Standards



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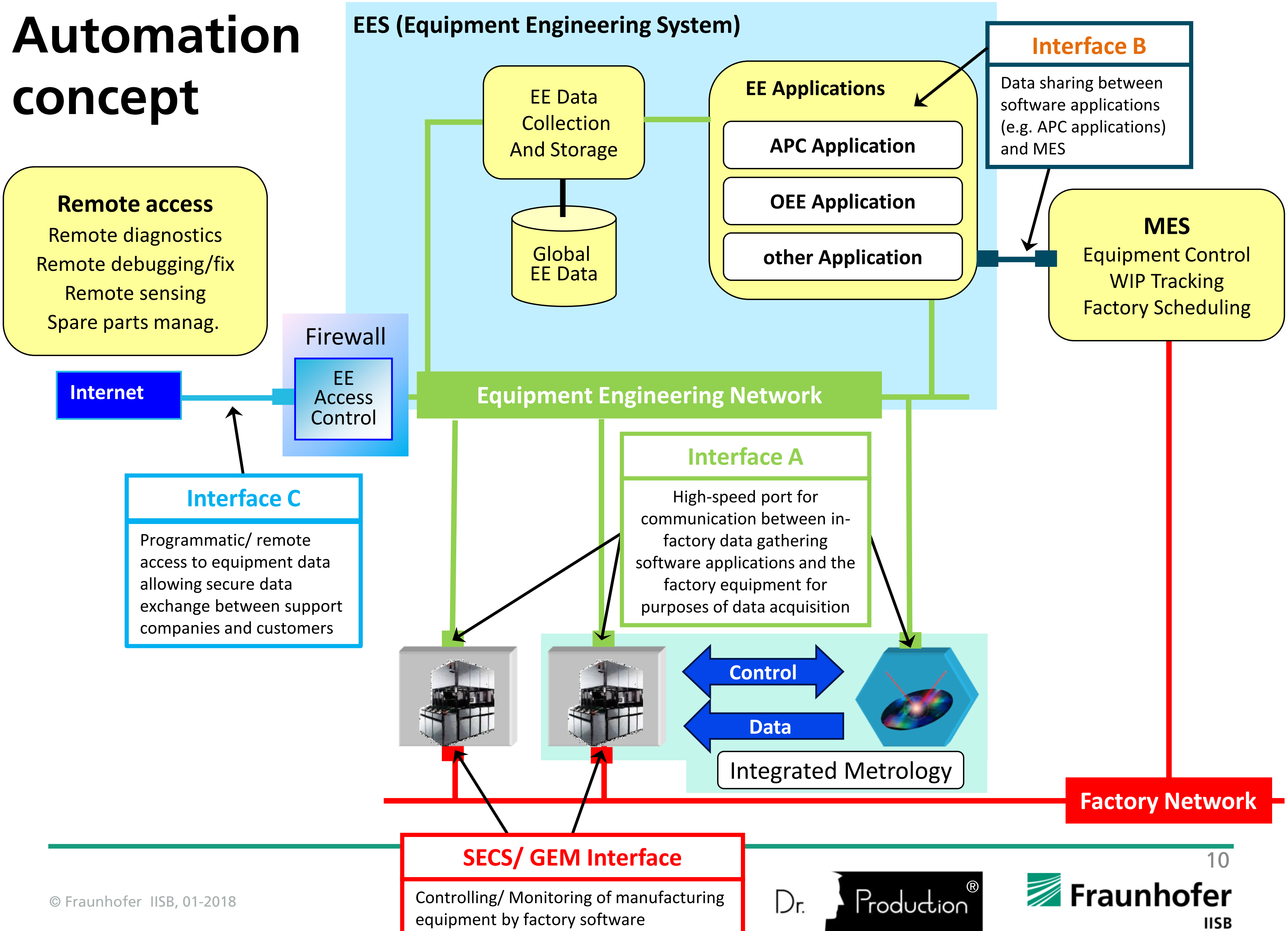
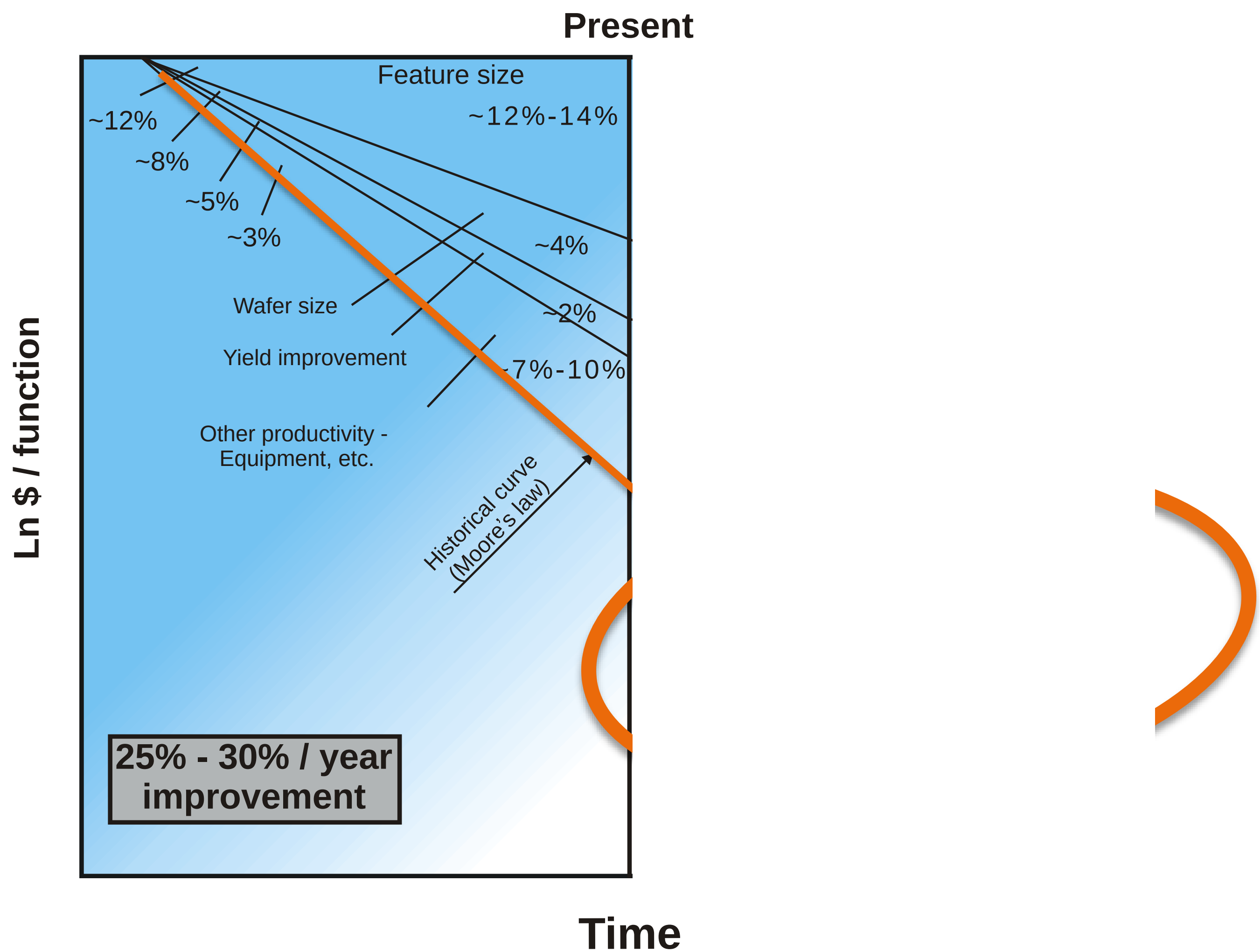
Referring to: http://www.semi.org/en/sites/semi.org/files/docs/AUX023-00-1211.pdf (15.03.2012)

Automation concept



Semiconductor Manufacturing

Bridge the “productivity gap” by Advanced Process Control (APC)



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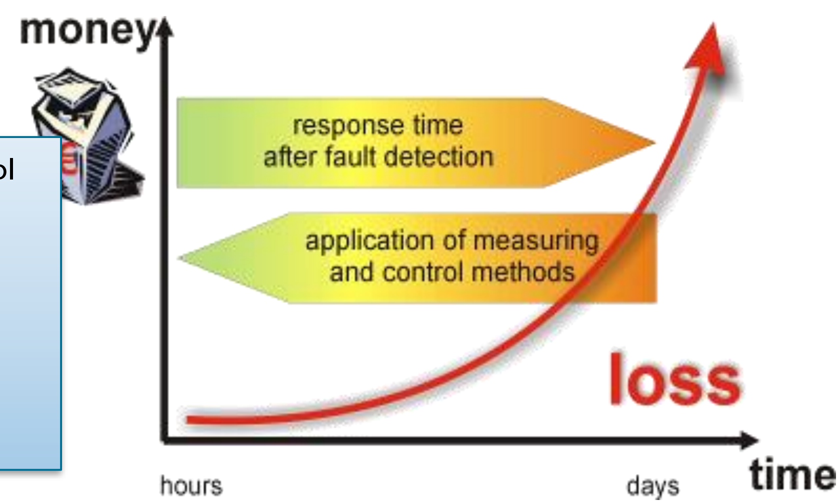
„Big data“ and Advanced Process Control

- 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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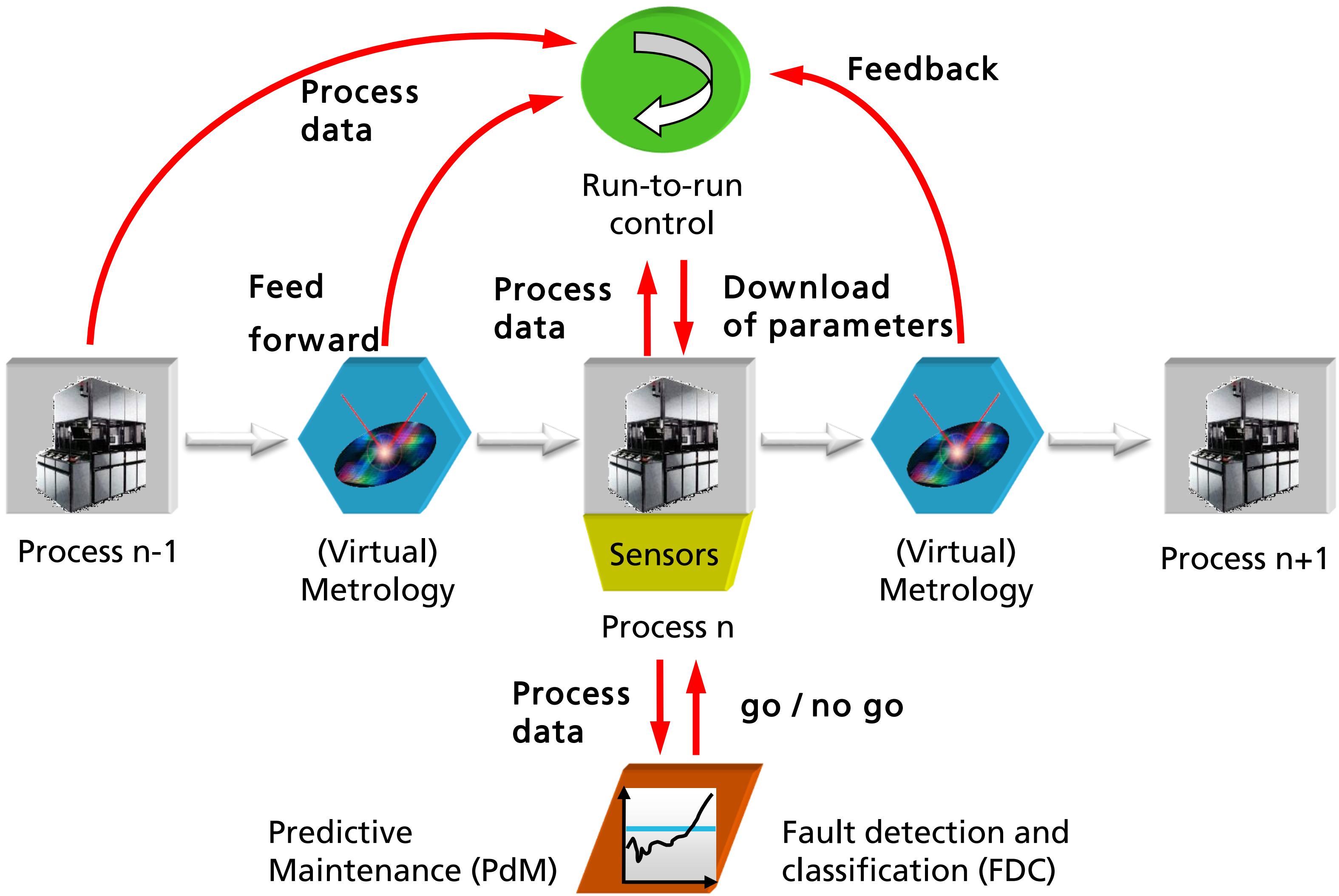
Interaction of APC elements



Agenda

1. Industry 4.0 in Semiconductor Manufacturing
2. **Dr. Production, Predictive Maintenance and Beyond**
3. Outlook

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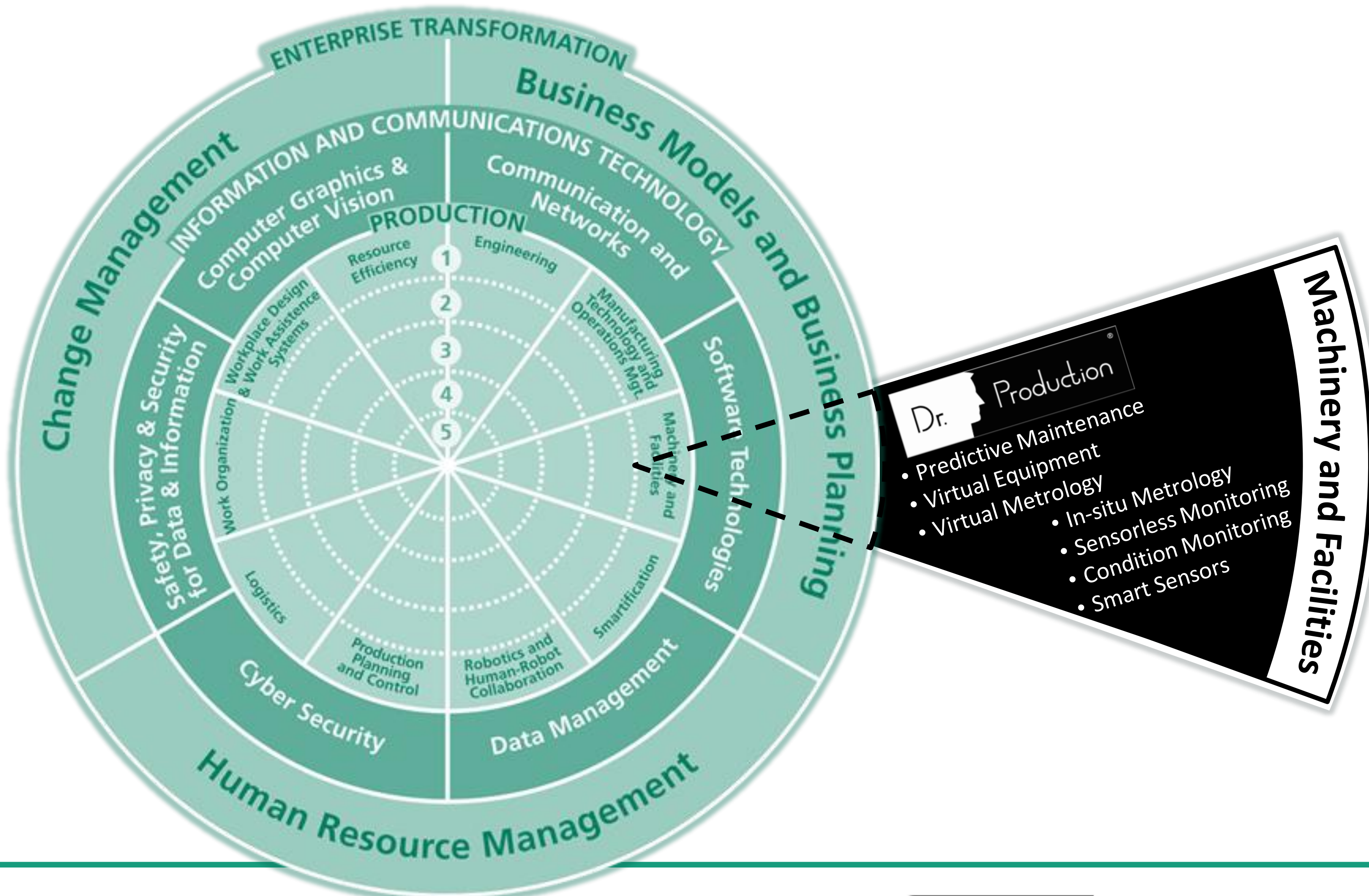
Part of the Fraunhofer Layer Model of Industry 4.0 Value Creation



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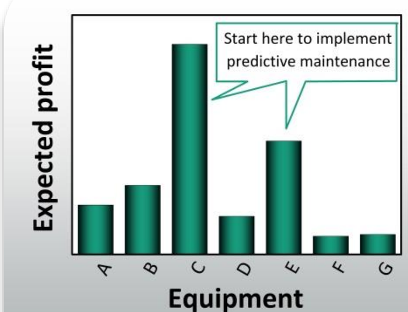
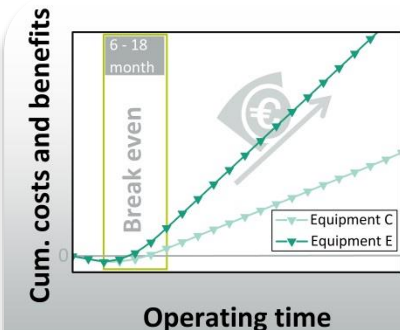
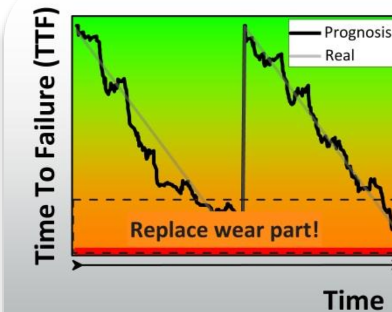
The Building Blocks – Industry 4.0 Components in a Nutshell



Individual Consulting and Conception



Analysis of Production Process and relevant Data



Development of intelligent Algorithms

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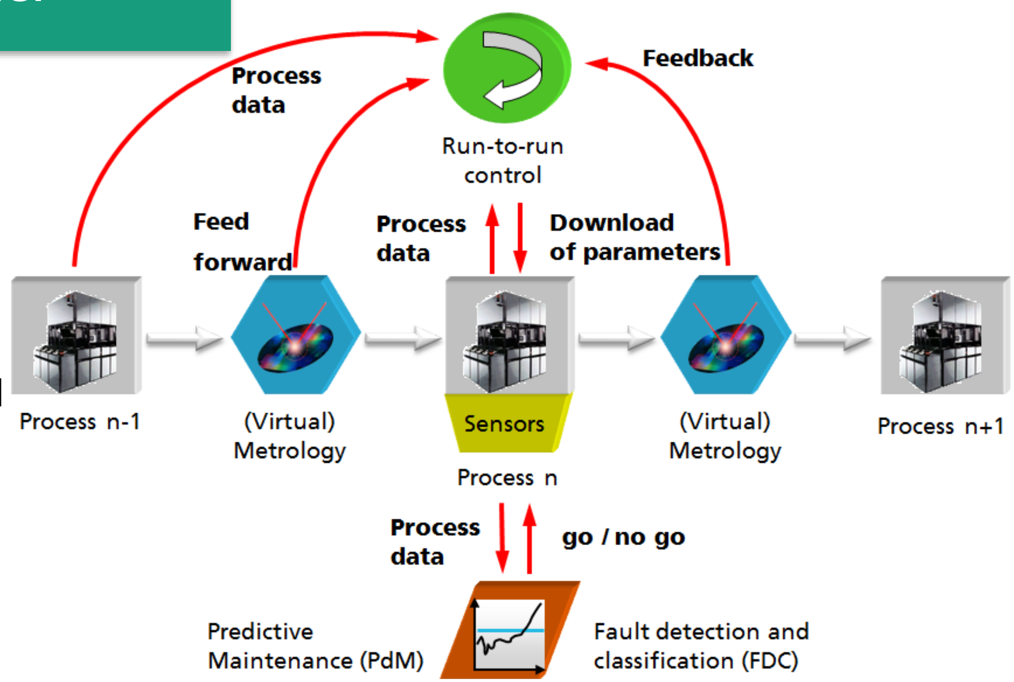
The Building Blocks: Analysis of Manufacturing Processes & Data Acquisition/Analysis

Data-driven manufacturing optimization provides a variety of optimization methods –
we will help to find the right one.

- *Fault detection and classification* uncovers anomalies of systems/processes
- *Run-to-run control* automatically modifies process parameters to improve process results
- *Predictive maintenance* predicts the need for service and maintenance measures
- *Virtual metrology* enables the data-driven prediction of quality parameters



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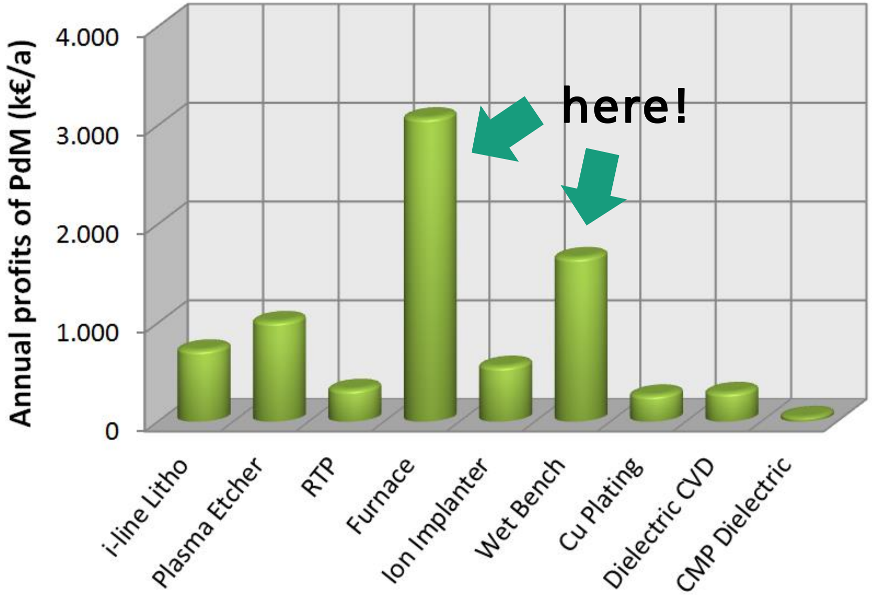
The Building Blocks: Consulting & Conception

We develop concepts for step-by-step implementation of data-driven production optimization and we clarify necessary conditions.

Where to start?

Example: *The benefits of implementing predictive maintenance through introduction of data-driven production optimization is greatly depending on the target equipment (right: analysis in semiconductor manufacturing).*



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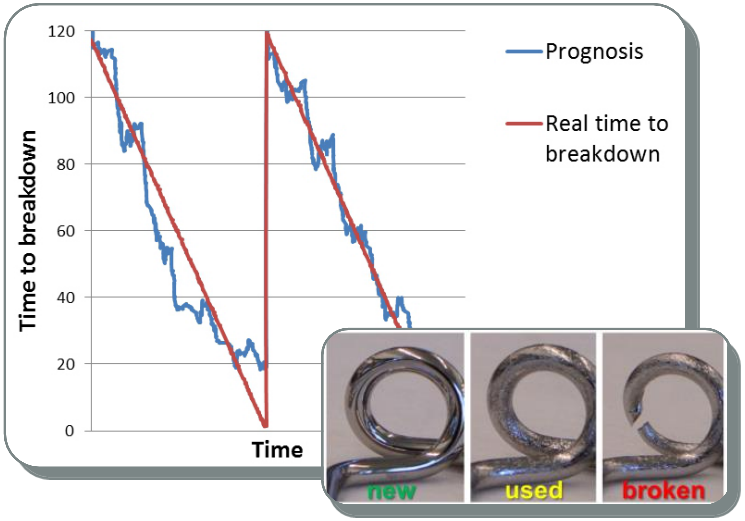
The Building Blocks: Development of Intelligent Algorithms (1/5)

We develop intelligent algorithms that analyze production data in real time and suggest or take necessary measures.



Example 1:
Predictive maintenance in ion-implantation

Relevant data are continuously collected and analyzed using a Bayesian network. The network predicts the real time remaining until the break of the filament with an accuracy of 10-20 hours.

Based on these forecasts, the maintenance tasks can be scheduled exactly. Thus, no "mere" preventive maintenance after a predetermined operating time or number of processes needs to be carried out, and no system failures are risked by missed maintenance steps.

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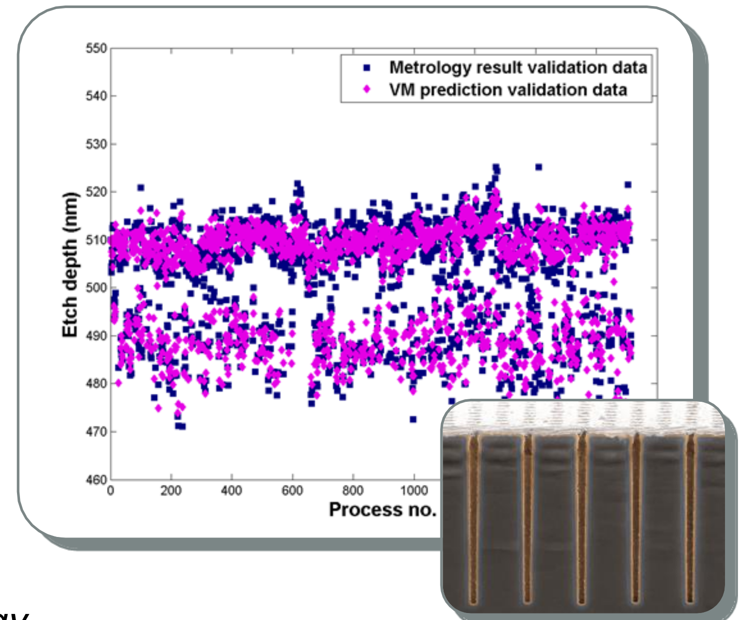
The Building Blocks: Development of Intelligent Algorithms (2/5)

We develop intelligent algorithms that analyze production data in real time and suggest or take necessary measures.



Example 2:
Virtual metrology for deep-trench etching

Relevant data are continuously collected and evaluated using a "gradient boosting tree" algorithm. The algorithm predicts the actual depth of the trench after the etching process with a deviation of less than 4 nm compared to values obtained from physical metrology.

The application of virtual metrology allows "virtual" control of every single wafer, while regular, costly and time-consuming physical measurements can be limited.

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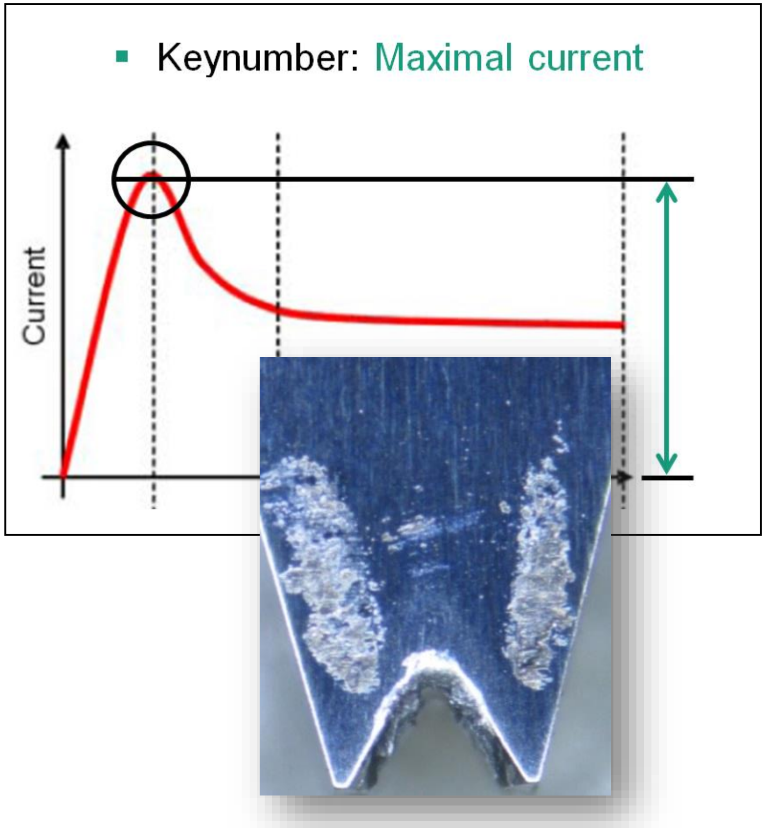
The Building Blocks: Development of Intelligent Algorithms (3/5)

We develop intelligent algorithms that analyze production data in real time and suggest or take necessary measures.

Example 3: Predictive maintenance in wire-bonding

Relevant data are continuously collected and evaluated to correlate quality parameters and equipment parameters with the wear status of the wedge.

First results show potential for an optimized wedge tool usage.



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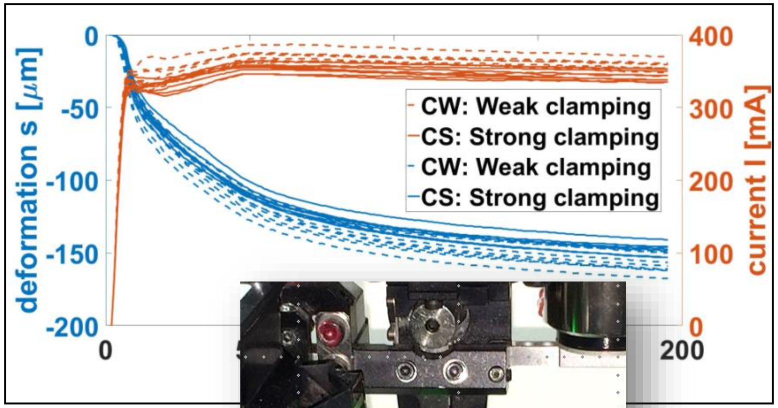
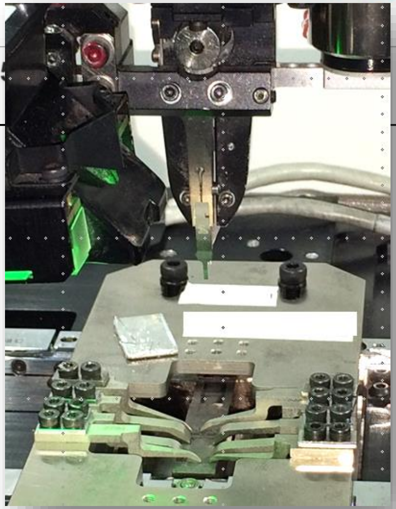
The Building Blocks: Development of Intelligent Algorithms (4/5)

We develop intelligent algorithms that analyze production data in real time and suggest or take necessary measures.





Example 4:
Detection of critical equipment states related to manual interaction

Relevant data are continuously collected and correlated to equipment states that cannot be measured directly (e.g. state of clamping, torque).

First results show that the algorithm is able to detect critical equipment states and to give measures for optimization.

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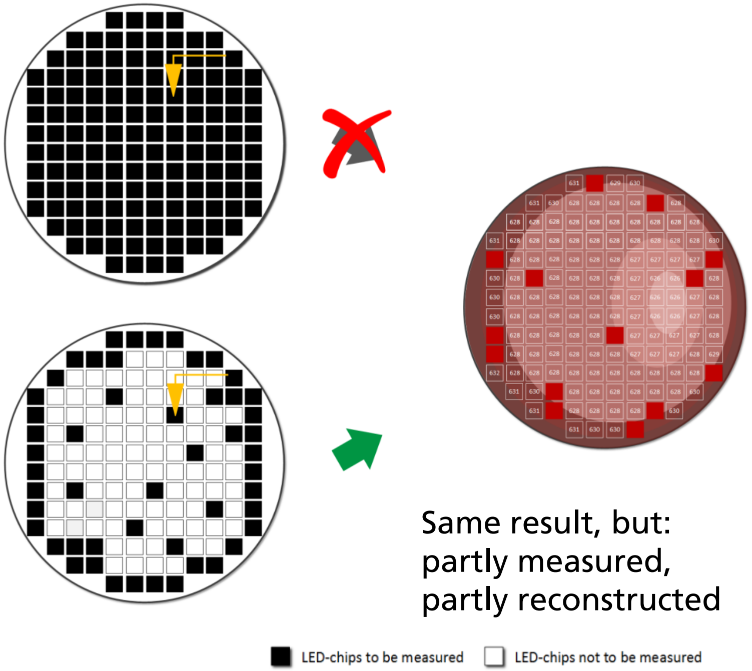
The Building Blocks: Development of Intelligent Algorithms (5/5)

We develop intelligent algorithms that analyze production data in real time and suggest or take necessary measures.

Example 5:
Predictive Probing to reduce time for device test

Relevant data from upstream processes are continuously collected and analyzed to predict device properties without actually measuring them.

Accurate interpolation of LED properties with < 5% measured chips achieved, with significant time and cost savings.



Same result, but:
partly measured,
partly reconstructed

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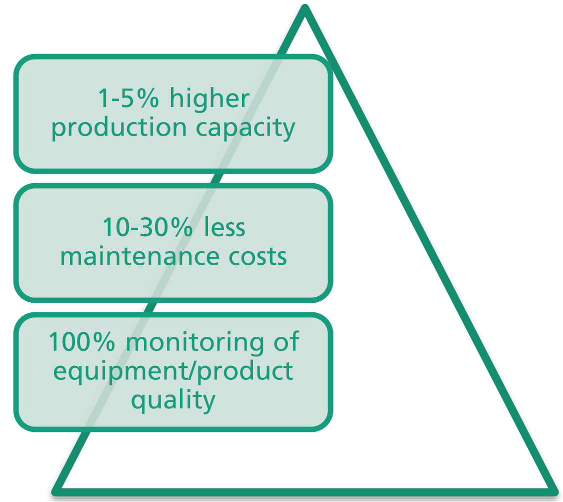
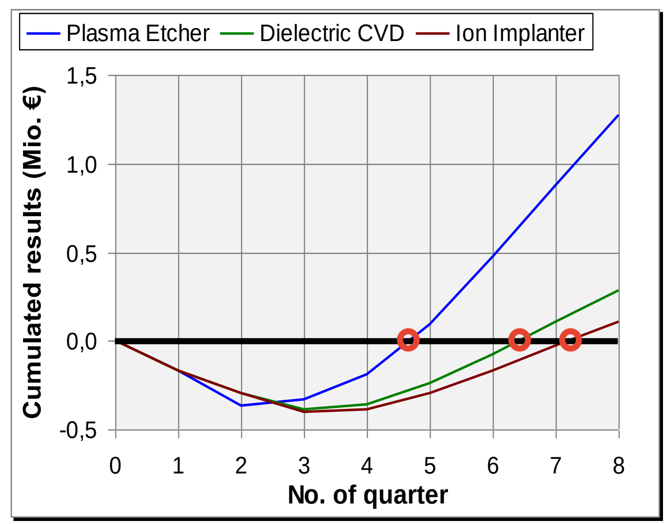
The Benefits

We have validated the monetary benefits through the use of data-driven production optimization in several reference projects.



Typical benefits from the introduction of predictive maintenance.

Example: *Amortization of the cost of predictive maintenance (hardware, software, implementation costs, ...) in various systems in semiconductor manufacturing in less than 24 months.*



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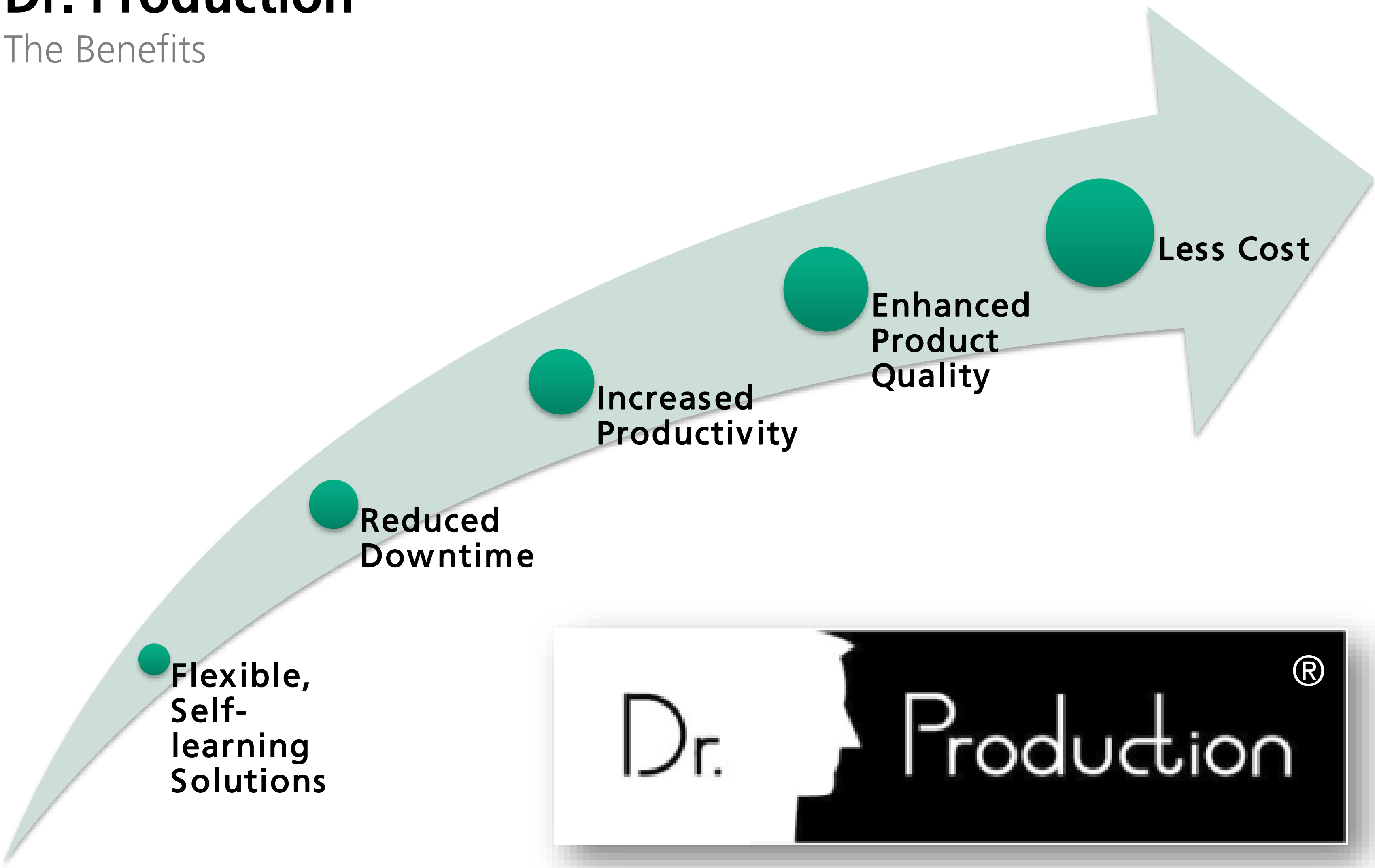
The Benefits



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3. **Outlook**

Electronic Systems

From Materials to Power Electronic Applications – Everything from One Source

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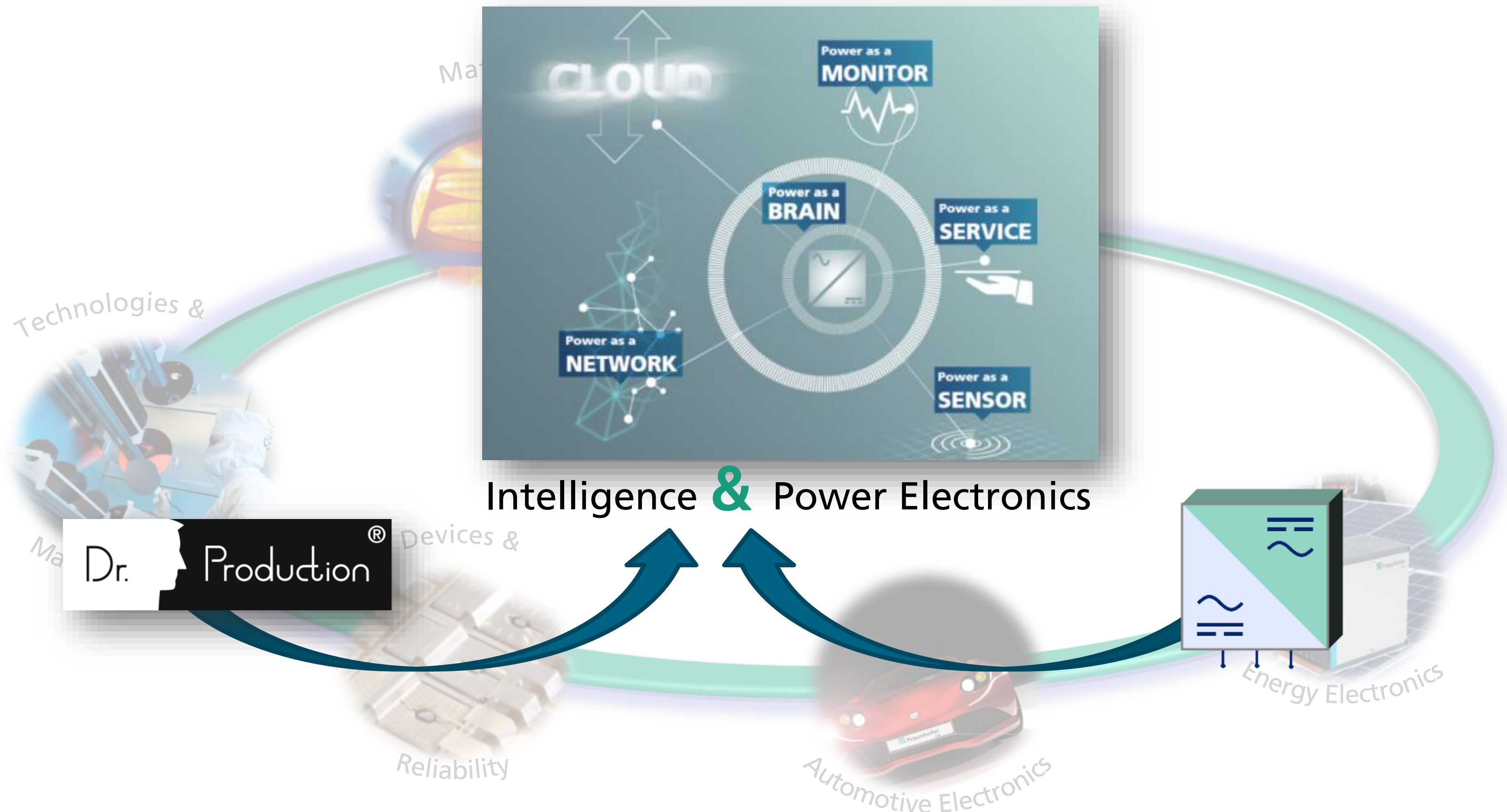
Cognitive Power Electronics 4.0



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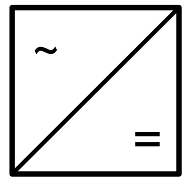
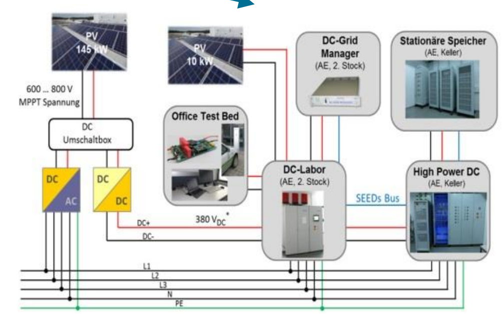
Outlook

Cognitive Power Electronics 4.0





Vacuum System

- Condition Monitoring
- Predictive Maintenance

Equipment

- Fault Detection and Prediction
- Process Optimization
- Predictive Maintenance

Intelligent Grid

- Control, Stability
- Optimiziation of Interaction: Source – Storage – Load

Outlook

The Chance of Working Together

Lessons learned from I4.0 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 (beyond industry segments)

Acknowledgement

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- **IMPROVE** (ENIAC Joint Undertaking, project ID: 12005)
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- **INTEGREAT** (BMBF funded)

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Thank you for your interest!

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