THE USE OF DIGITAL TWIN TECHNOLOGY IN BATTERY DESIGN AND MANUFACTURING

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Batteriestammtisch, 30.01.2020, München

Agenda

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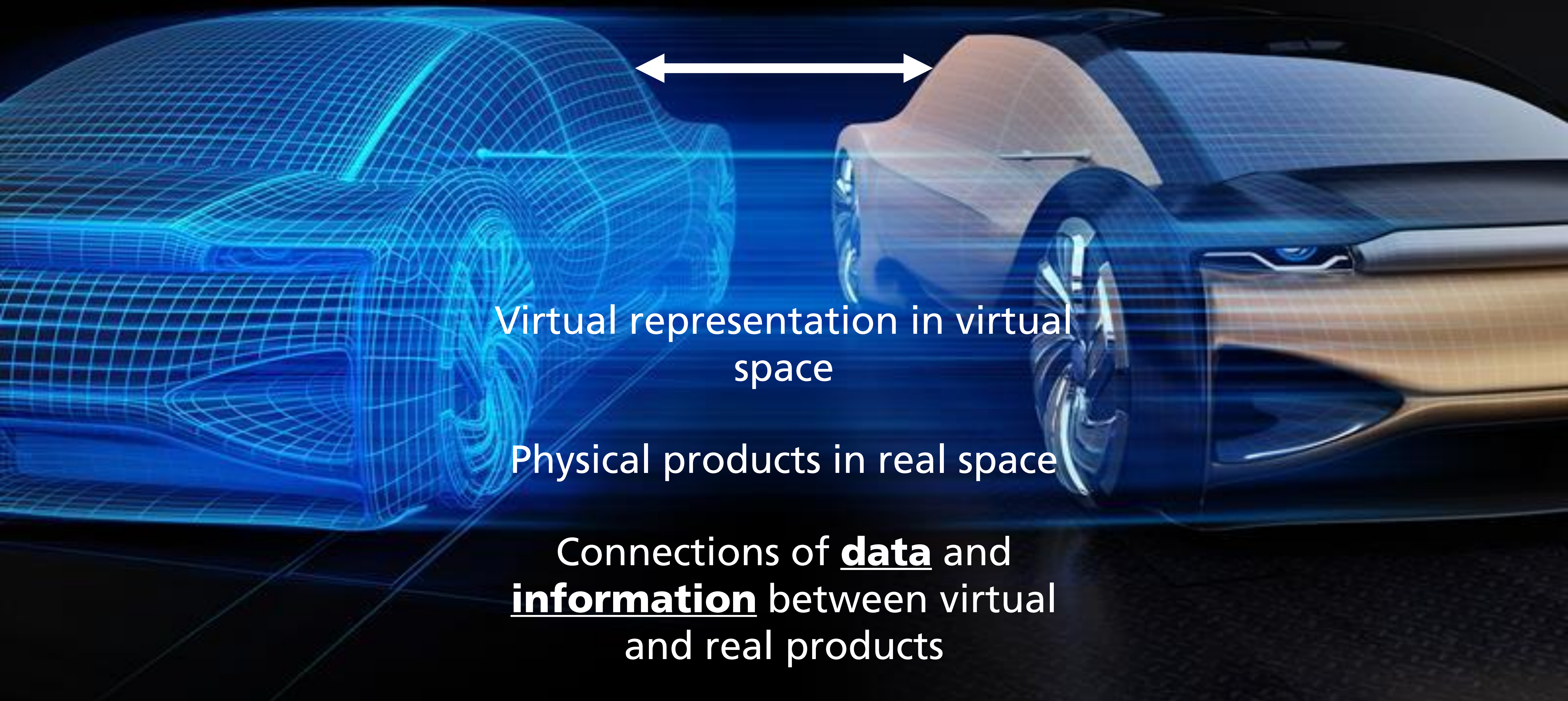
Digital Twin Technology



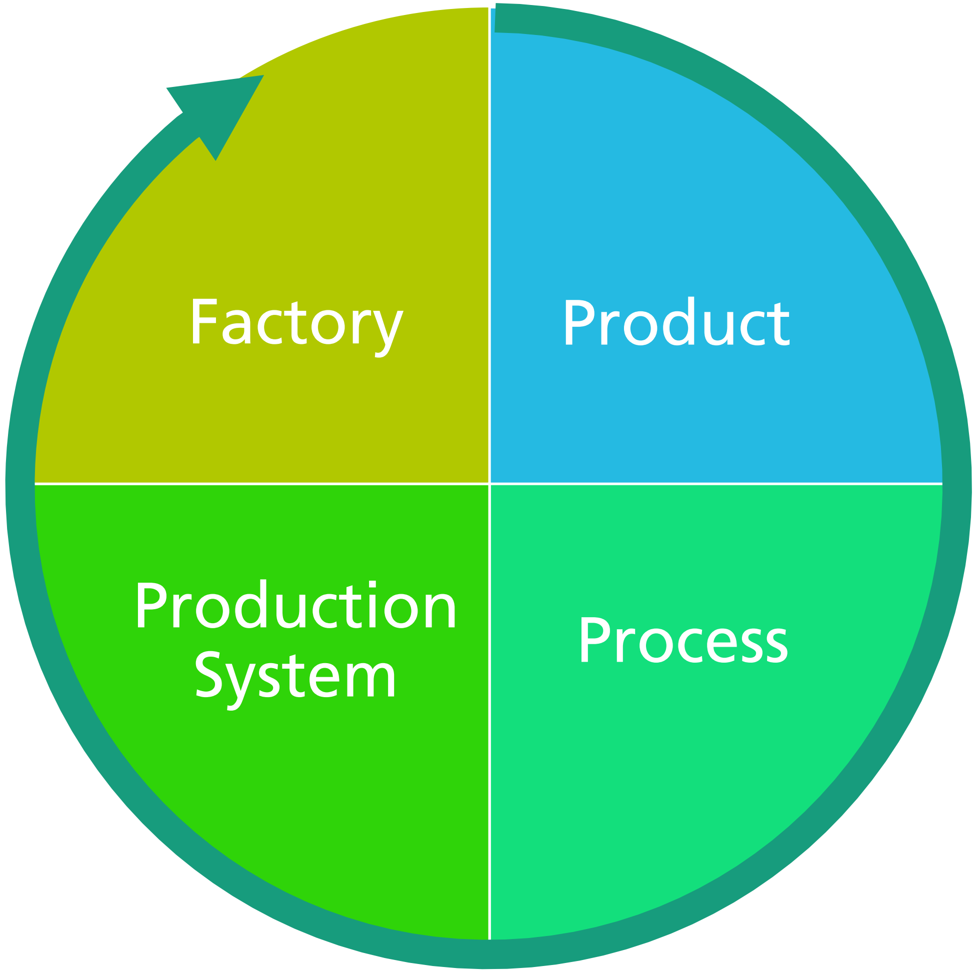
Virtual representation in virtual space

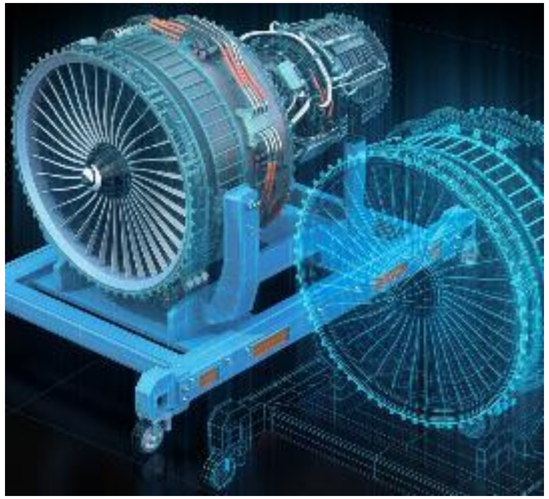
Physical products in real space

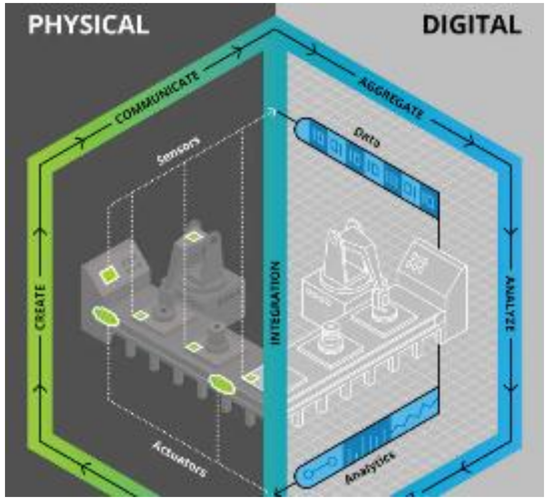
Connections of **<u>data</u>** and **<u>information</u>** between virtual and real products

Digital Twin Technology

Where? - Classification of Digital Twins







http://7cc.00d.mwp.accessdomain.com/digital-twin/
https://docplayer.net/53847218-Tecnomatix-plant-simulation-world-wide-user-conference-2016.html

https://job-wizards.com/de/digital-twin-die-doppelte-chance-fuer-innovationsmoeglichkeiten/
https://www2.deloitte.com/us/en/insights/focus/industry-4-0/digital-twin-technology-smart-factory.html

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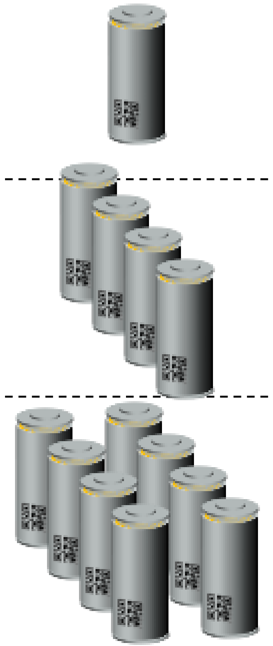
And in case of Battery cells and Battery Technology?

Multi-Hierarchy Digital Twin

Design → Manufacturing → Usage & End of Life

product life cycle

Digital Twin	Cell	
Digital Twin	Module	
Digital Twin	System	



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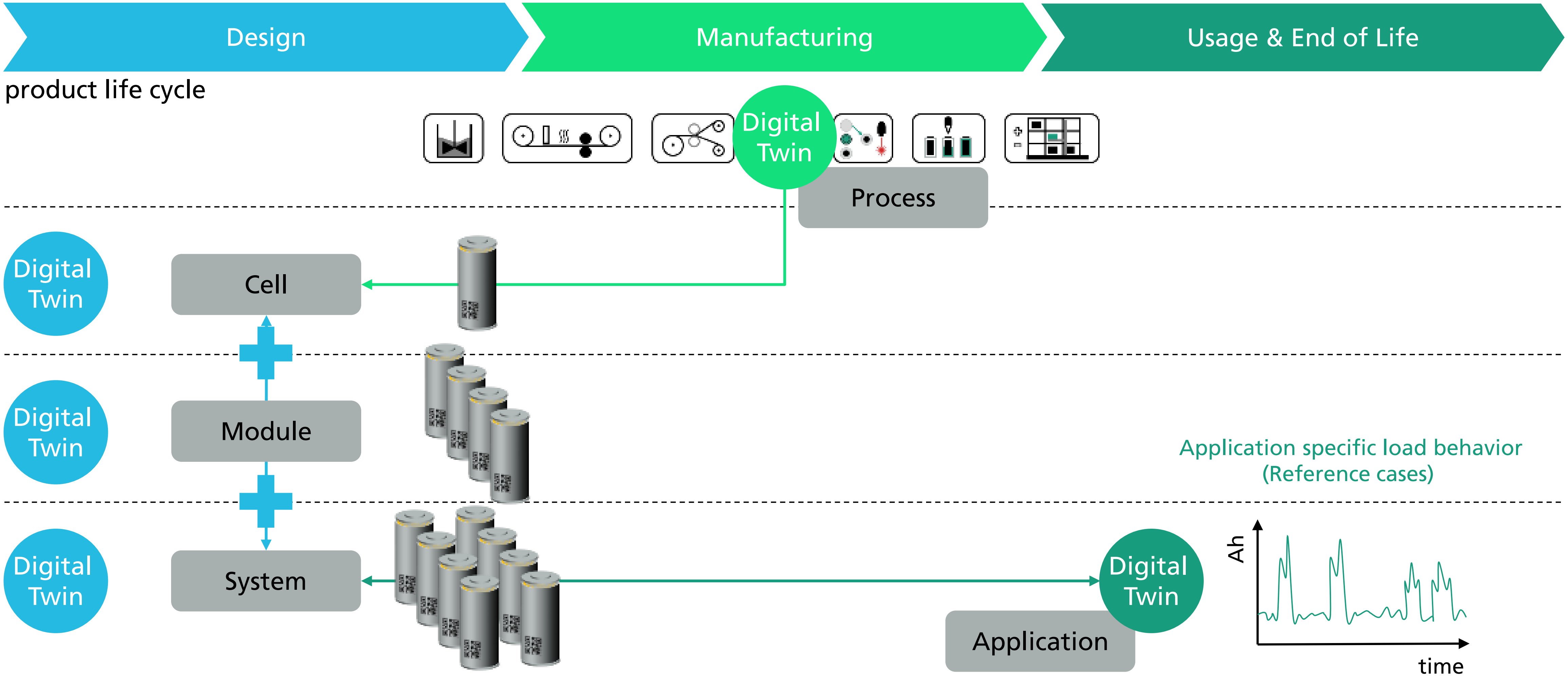
And in case of Battery cells and Battery Technology?
Process Digital Twin



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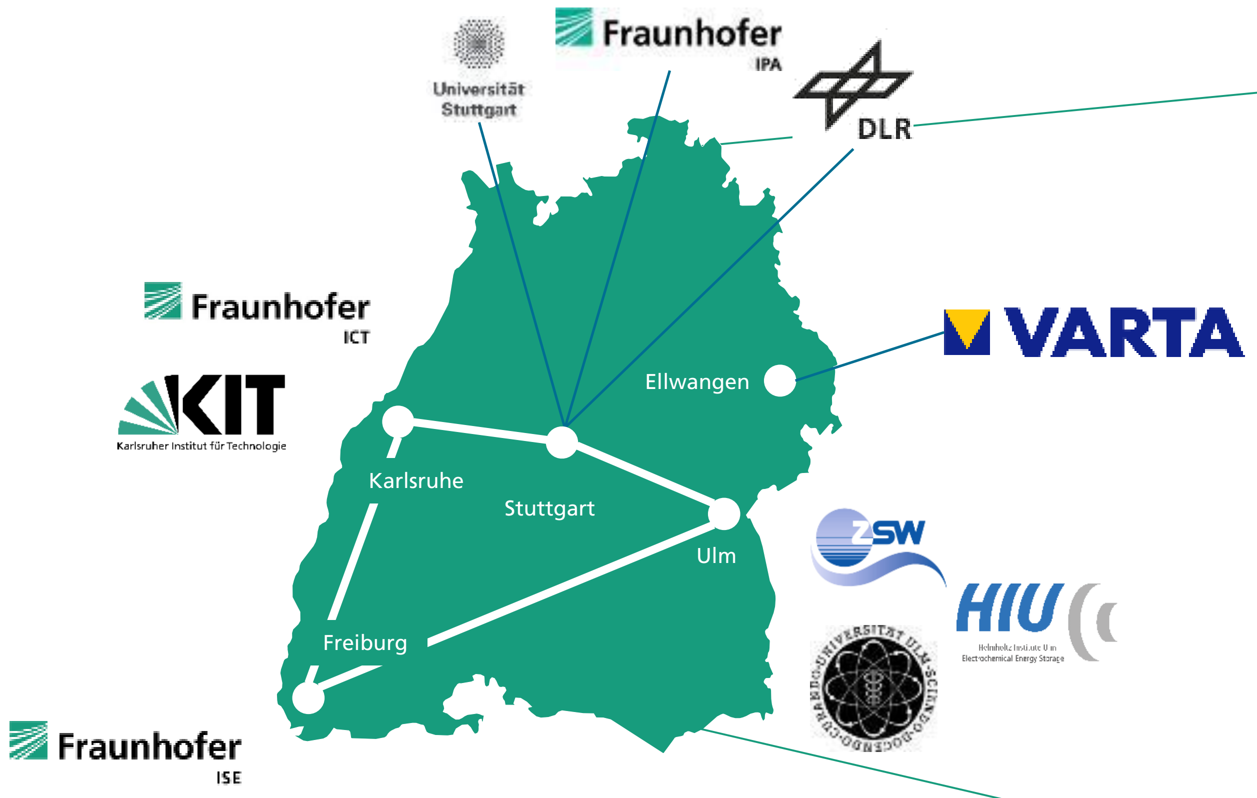
Center for Battery Cell Manufacturing

Adding manufacturing competencies to the research networks



Universities of Applied Science

Hochschule Esslingen
University of Applied Sciences

HOCHSCHULE FURTWANGEN UNIVERSITY HFU

Industry

PORSCHE

VARTA

DAIMLER

FARASIS

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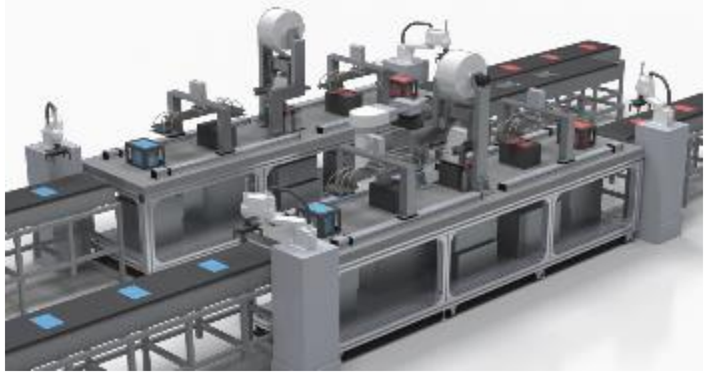
Center for Battery Cell Manufacturing
IoT-Architecture and Digital Services, Modelling and Simulation (Digital Twins)

Small-Scale Production	Center for Battery Cell Manufacturing	Large-Scale Production
		
• High flexibility • Low throughput < 100 parts/day • Low level of automation	• Medium flexibility • Low to medium throughput up to 300 parts/day • Medium level of automation	• Low flexibility • High throughput >> 1000 parts/day • High level of automation

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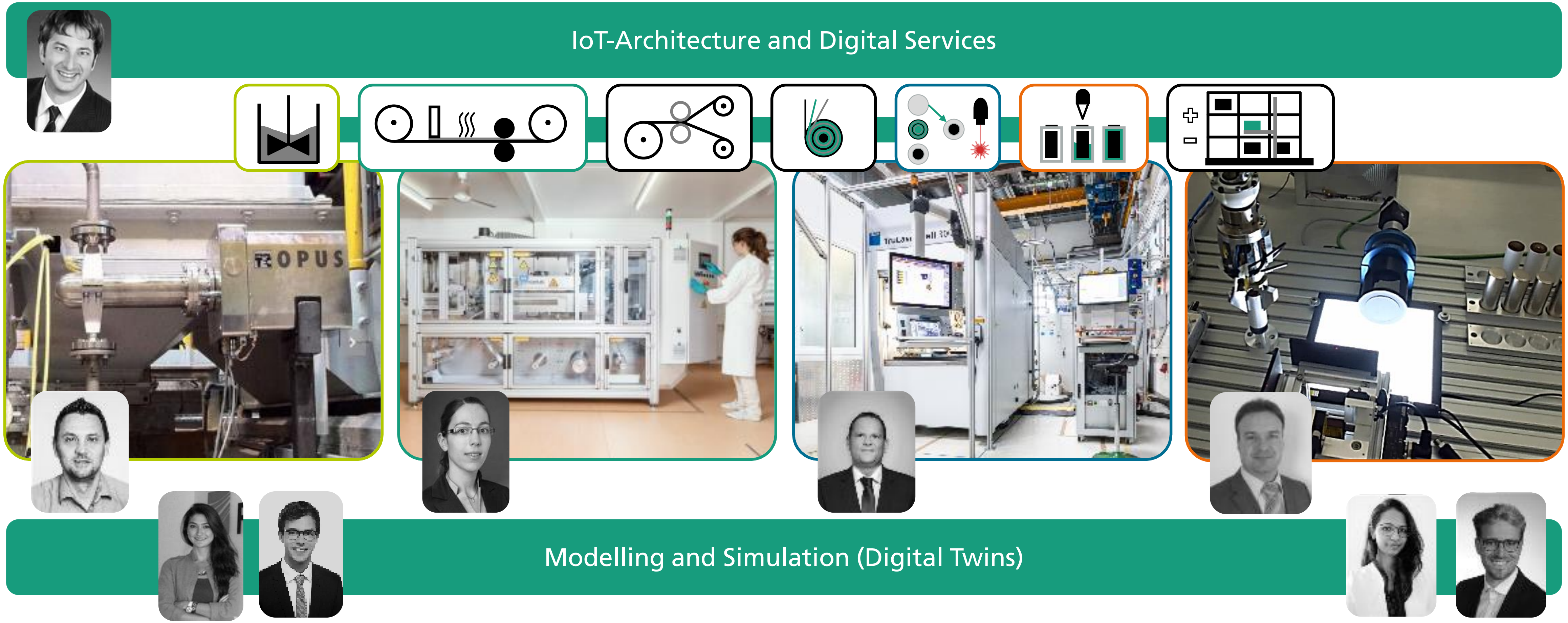
Center for Battery Cell Manufacturing
Researching the entire value chain



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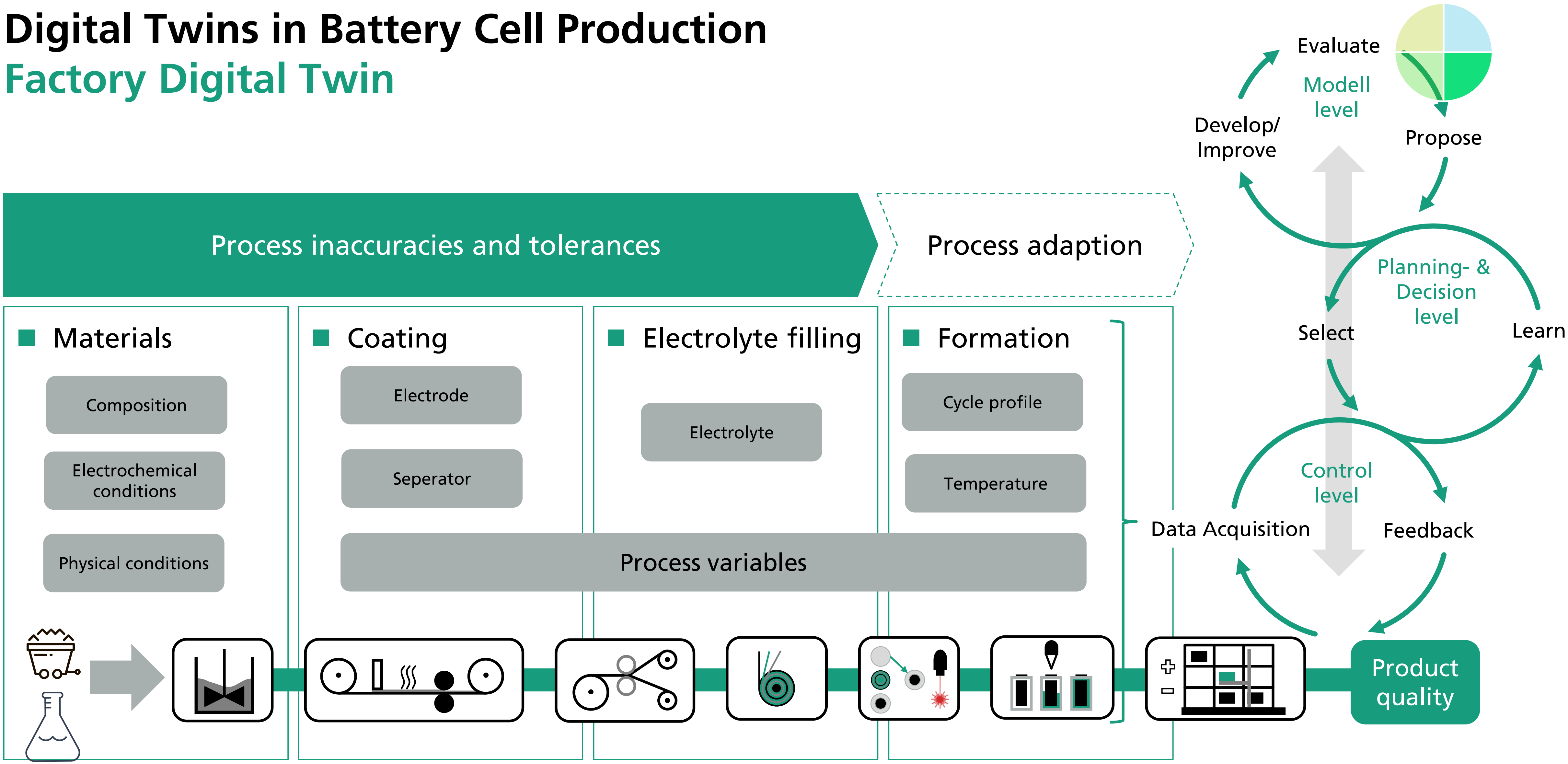
Digital Twins in Battery Cell Production
Factory Digital Twin



Source: Kindermann (2017) - Implications of Current Density Distribution in Lithium-Ion Battery Graphite Anodes on SEI

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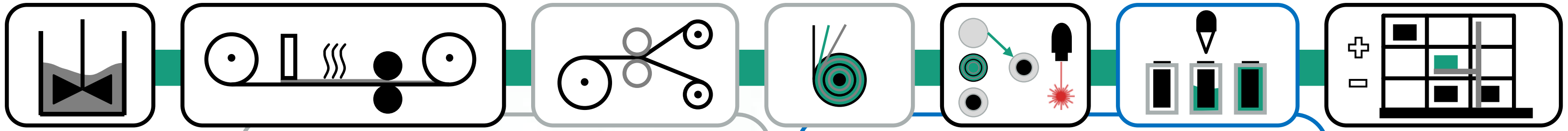
Electrolyte and Formation

IoT-Architecture and Digital Services



Modelling and Simulation (Digital Twins)

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Industry 4.0 capable, intelligent workpiece carriers
Principle

Beyond the functionality of conventional workpiece carriers, the workpiece carrier of ZDB enables the active communication with the manufacturing control (MES), the monitoring of environmental conditions for quality assurance and data analysis, the continuous tracking from goods inwards to outwards as well as the interaction with the operator during manual process steps.

Tracking of battery cells

Environmental monitoring – temperature and humidity of cleanroom and pilot plant

Gas sensors for detection of electrolyte

Dew point measurement in dry room

Active communication with manufacturing control based on software framework with MSB interface for cloud platform VFK

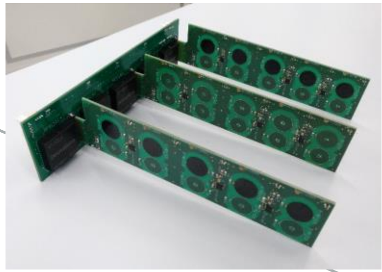
Weighing (process station) – workpieces and electrolyte

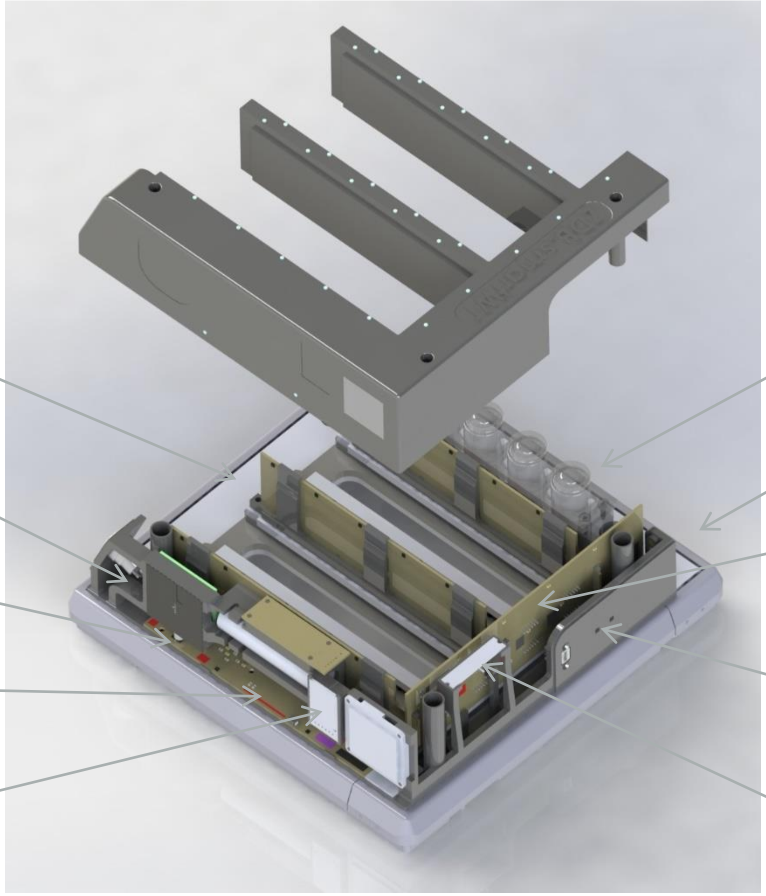
Support of manual process steps by detecting the removing and inserting of cells (inductive)

Industry 4.0 capable, intelligent workpiece carriers

Core components of workpiece carrier

Inductive sensors for detection of single battery cells (PCB)





Inductive energy transfer and battery monitoring

Piezo for acoustic feedback

Microcontroller on main PCB

Bidirectional NFC tag (PCB)

LEDs for operator guidance

Connector for dew point sensor

RFID and hall effect sensors for workpiece tray identification (PCB)

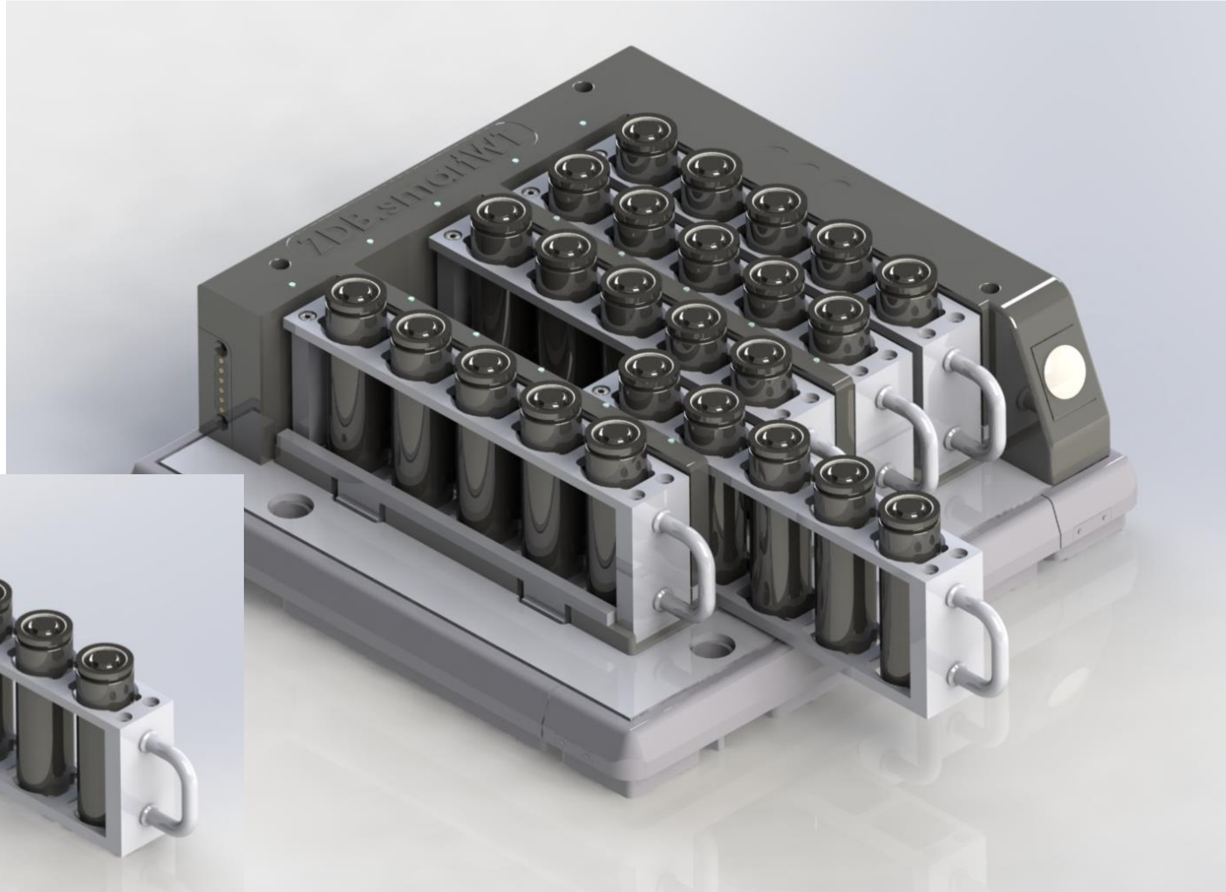
Sensors for temperature, humidity and VOC (PCB)

Wifi antenna

Industry 4.0 capable, intelligent workpiece carriers

Mechanical construction of workpiece carrier

- High packaging density through space-saving workpiece detection
- Trays are detectable and equipped with RFID tags for identification by the workpiece carrier
- Identification of trays enables the use of different workpiece carriers, e.g. in contamination sensitive environments
- Usage of workpiece carrier in whole process chain of ZDB



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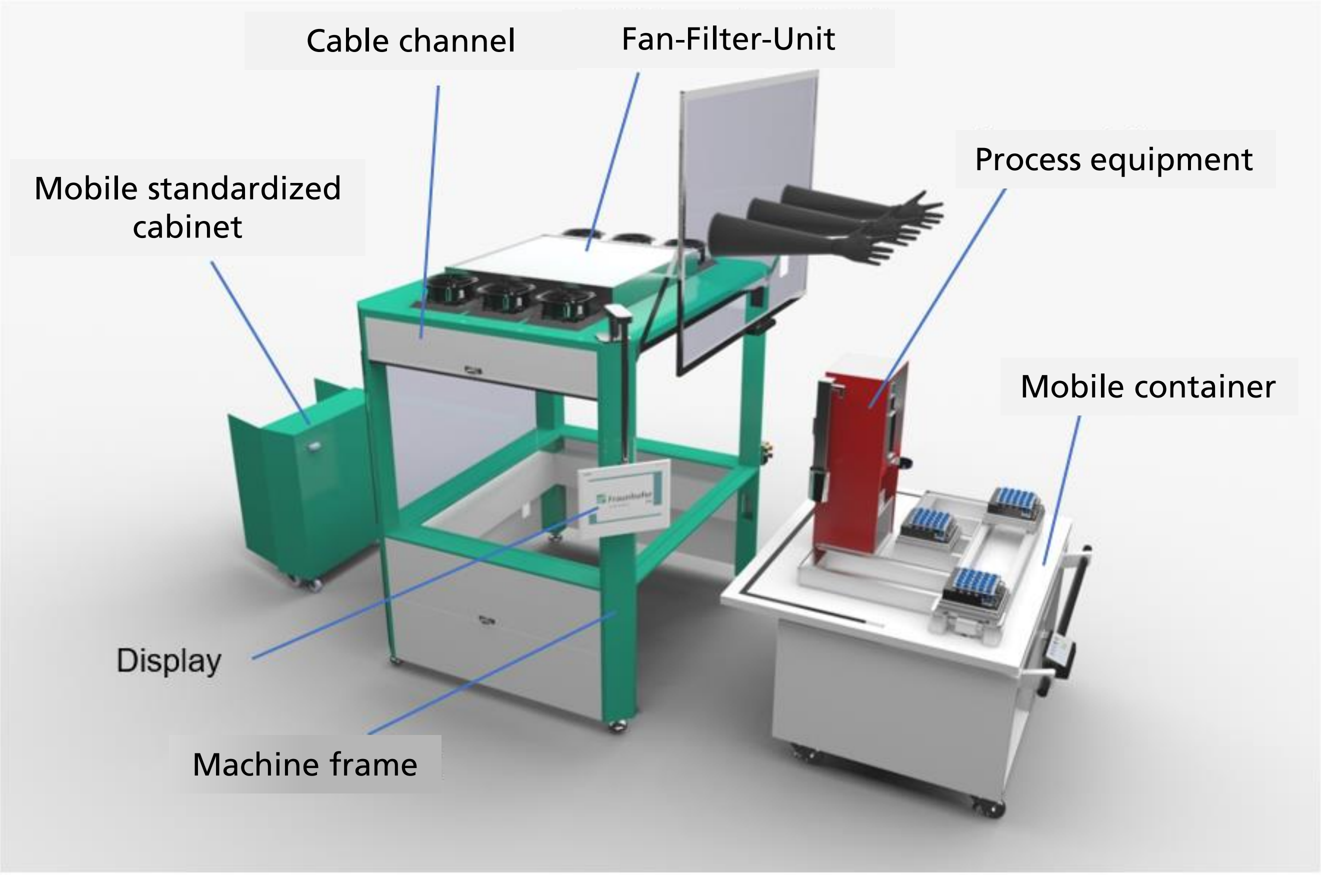
Concept of a Flexible Machine Platform for the Assembly of Lithium-Ion Cells
Layout



- **Mobile container** for the placement of process equipment
- **Machine Frame** for enclosing the process environment
- **Outer cable channel** for relocation, expanding and accessibility of supply cables and tubes
- **Mobile standardized cabinet** for supply of the mobile container and machine frame
- **Air filter system** and **air conditioning** (Fan-Filter-Unit) for producing the dry- and cleanroom conditions

Concept of Machine Platform
Example Electrolyte Filling

- **Electrolyte filling** has **highest requirements** of all processes
  - Process steps should be carried out under controlled environment

- **Assembly Sequence:**
  1. Cell bake out and apply to environment
  2. Filling cell with electrolyte
  3. Welding of cap
  4. Beading of cell
  5. Remove cell from environment

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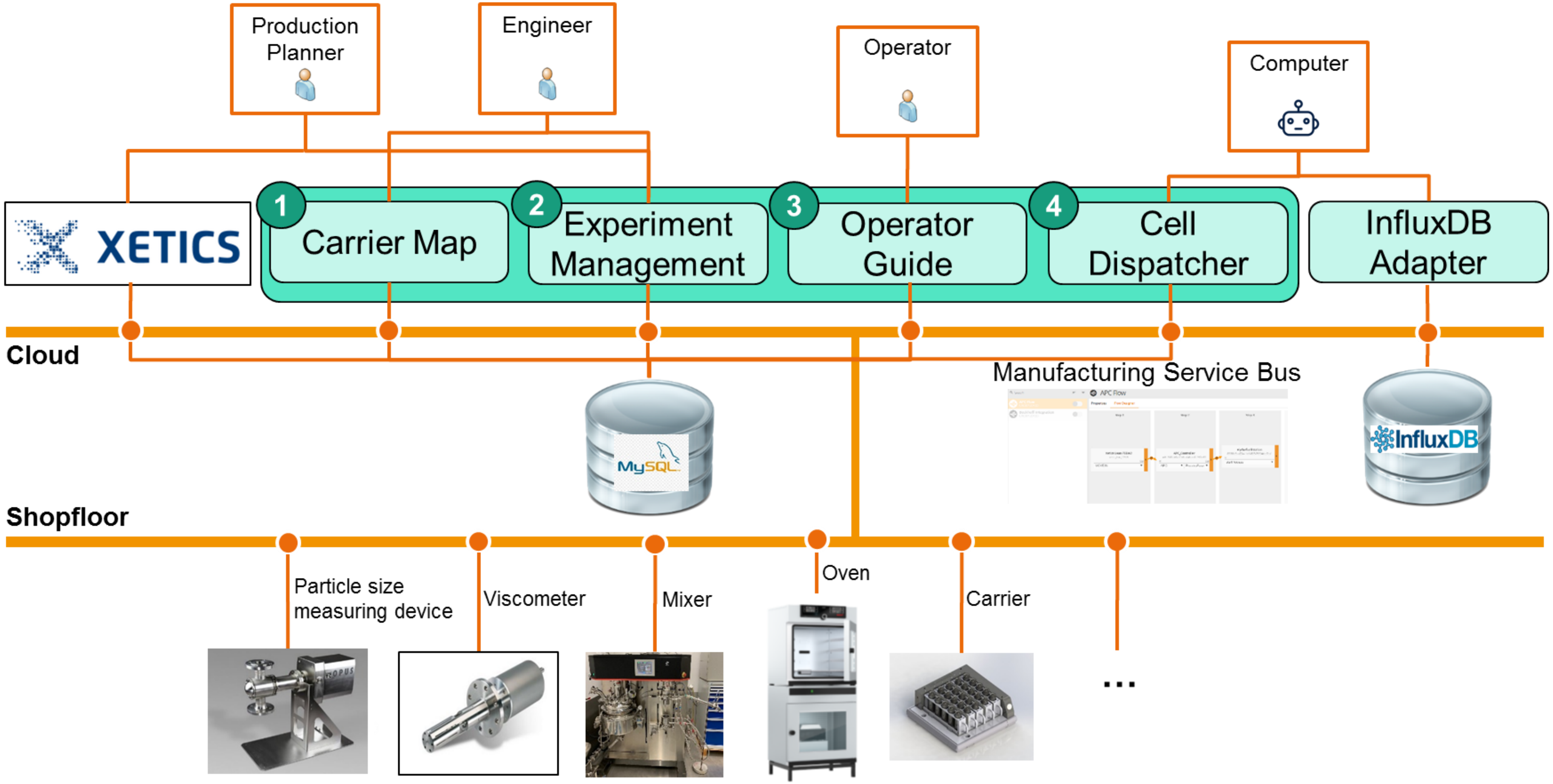
Cognitive Cyber-Physical Production System
Schematic Concept



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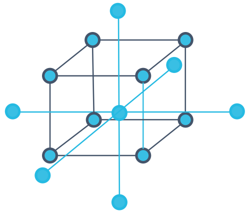
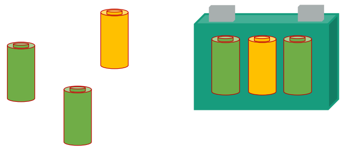
Digital Twin Technology – State estimation for battery cells
Determination of battery states

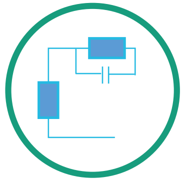
Testing | **Modelling** | **Decision Support**



Design of Experiments

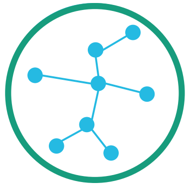


Cell   Module

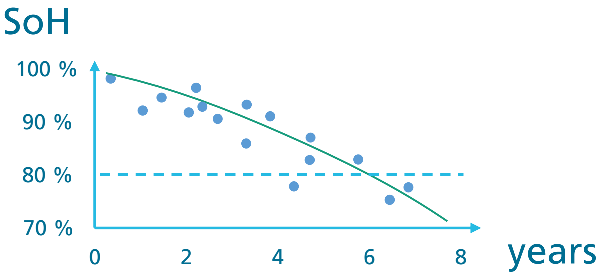


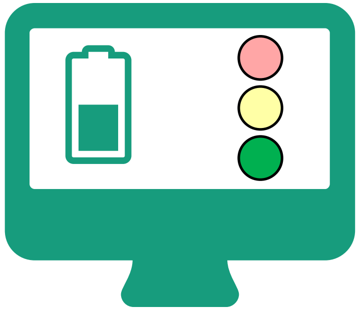
Physical Model

Regression Model



Machine Learning (ML) Model





*Source: Myall, D.; Ivanov, D.; Larason, W.; Nixon, M.; Moller, H. (2018) Accelerated Reported Battery Capacity Loss in 30 kWh Variants of the Nissan Leaf.

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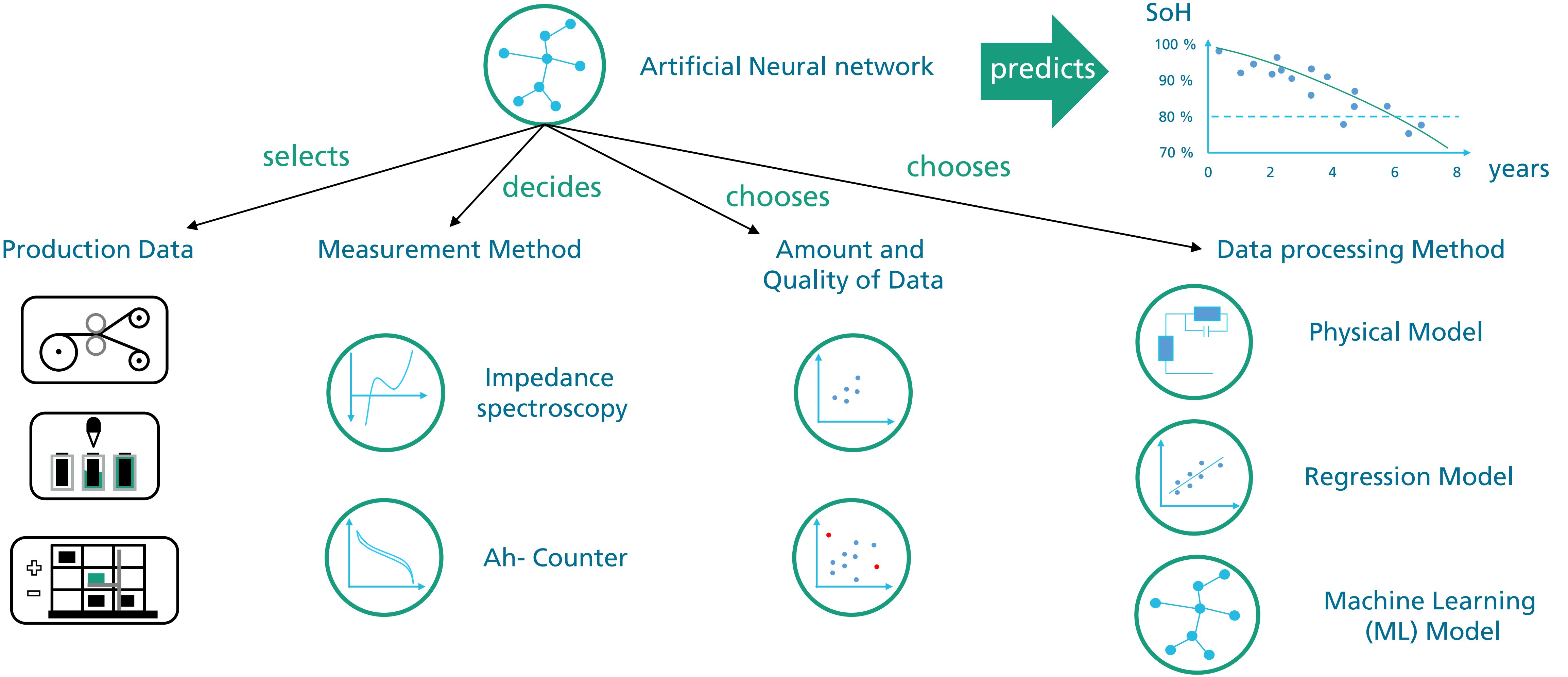
Digital Twin Technology – State estimation for battery cells
Determination of battery conditions



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Conclusions

1. **Digital Twin Technology accesses multiple aspects of battery cells and batteries**
2. **The most important are: Cell production, prediction of cell states (includes aging), cell design**
3. **Cell production: Data acquisition is the pathway to better cell performance and less deviations**
4. **Future vision: The factory digital twin of a battery cell allows also its aging prediction**
5. **Prediction of cell states: Less experimental data are required and higher prediction precision is feasible**
6. **Cell design can more and more rely on data acquisition in cell production, not on trial and error**

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The Team – Thank you!

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- Ozan Yesilyurt

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