KIT Karlsruhe Institute of Technology

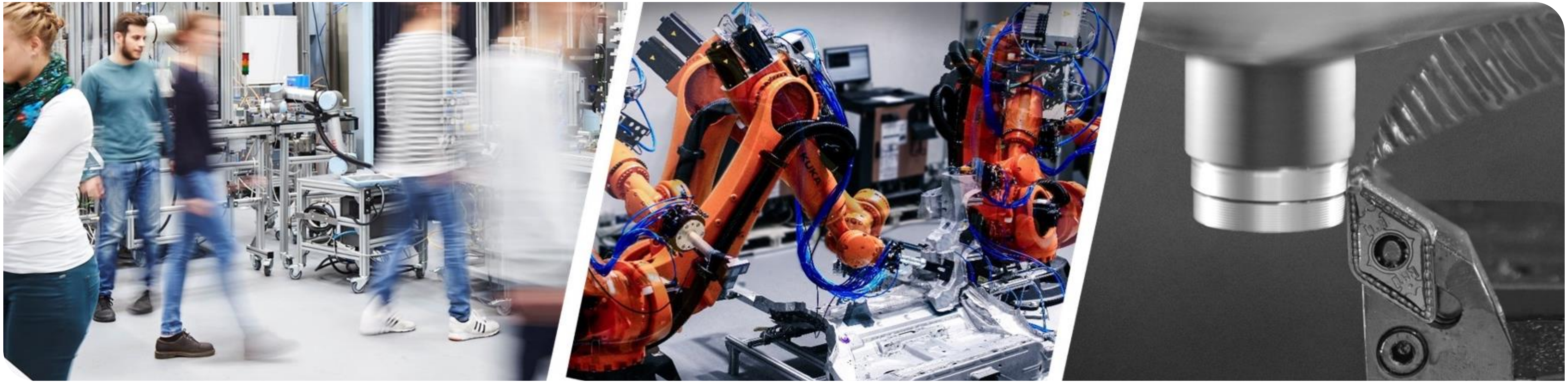
mim 2022 10th IFAC CONFERENCE

wbk Institute of Production Science

Changeable production by utilizing digital twins

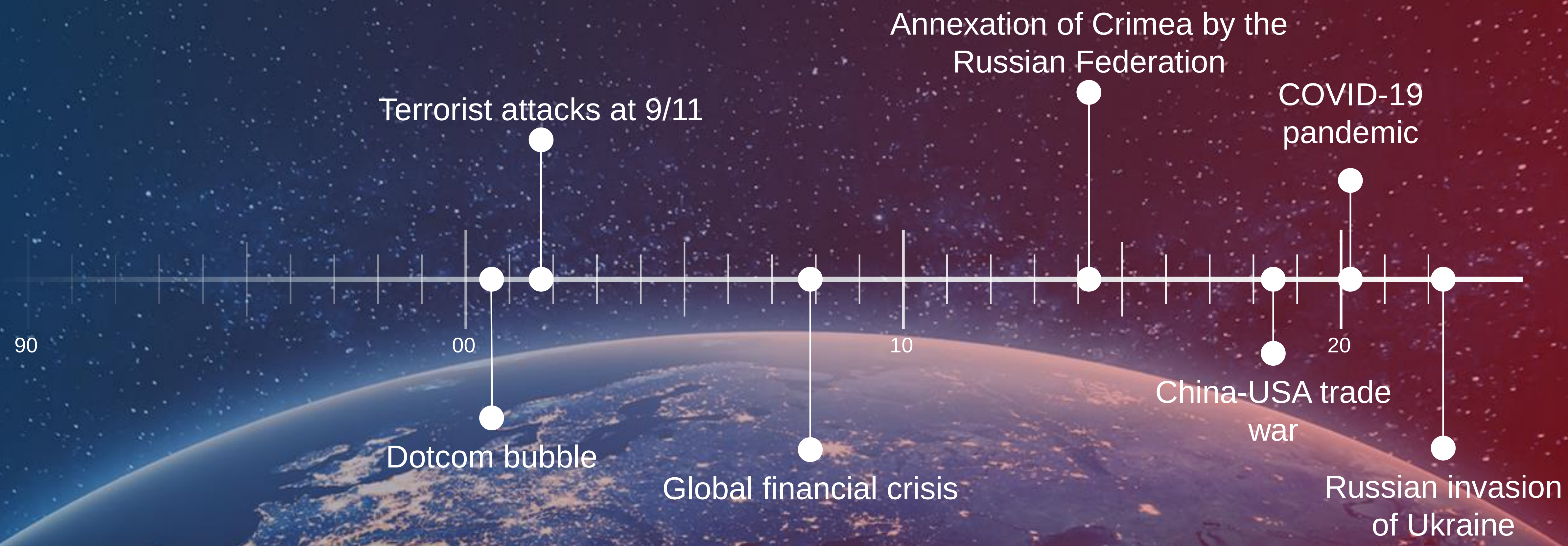
10th IFAC Conference on Manufacturing Modelling, Management and Control

Prof. Dr.-Ing. Gisela Lanza



Are we living in a time of increasing disruption and uncertainty?

Disruptive political and economic events since 1990



Institute of Production Science

Challenges of today's production environment

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Volatile markets require rapid responses

Uncertainty characterizes production operations

Complexity due to individualized mass production

Ambiguity of requirements for production

Industry 4.0

Sensors

Data availability

Hardware, IT and OT

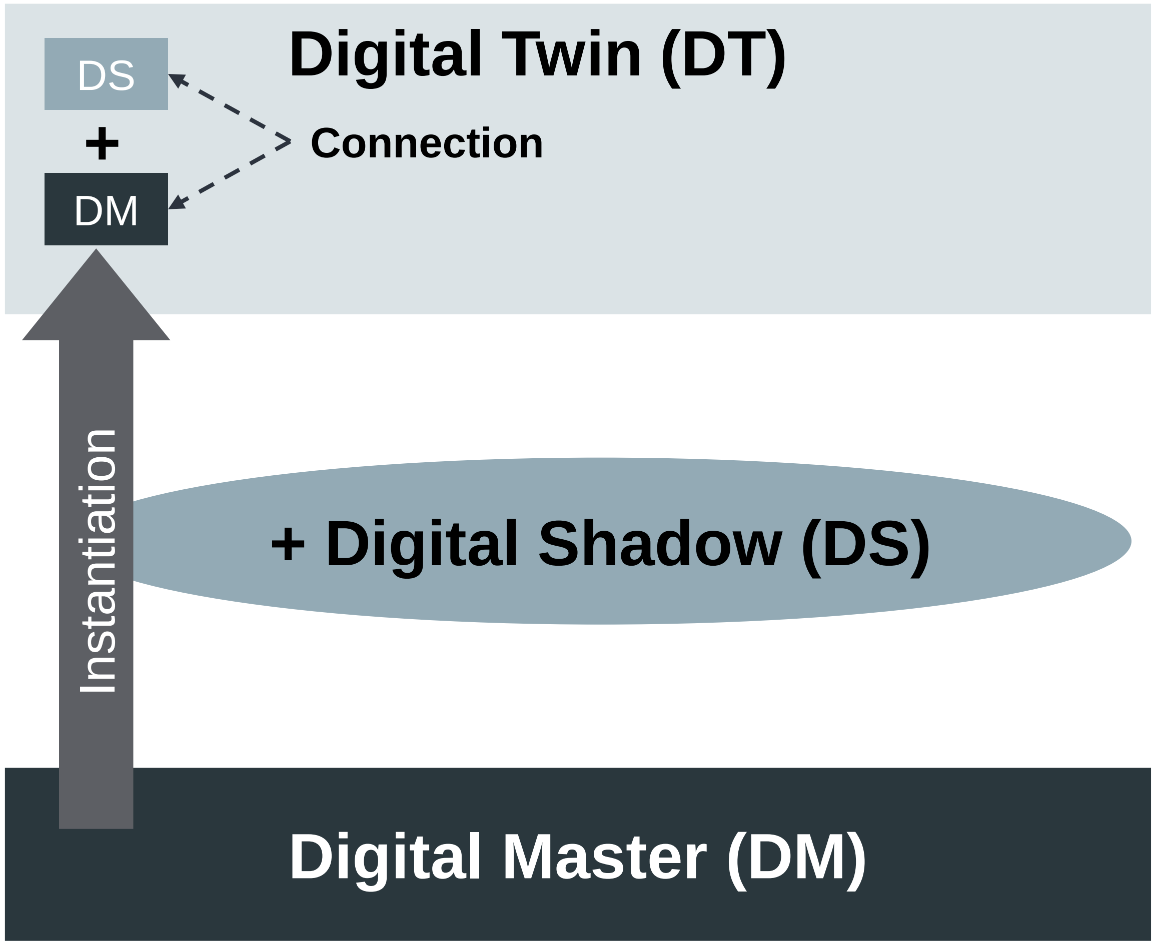
Data driven algorithms

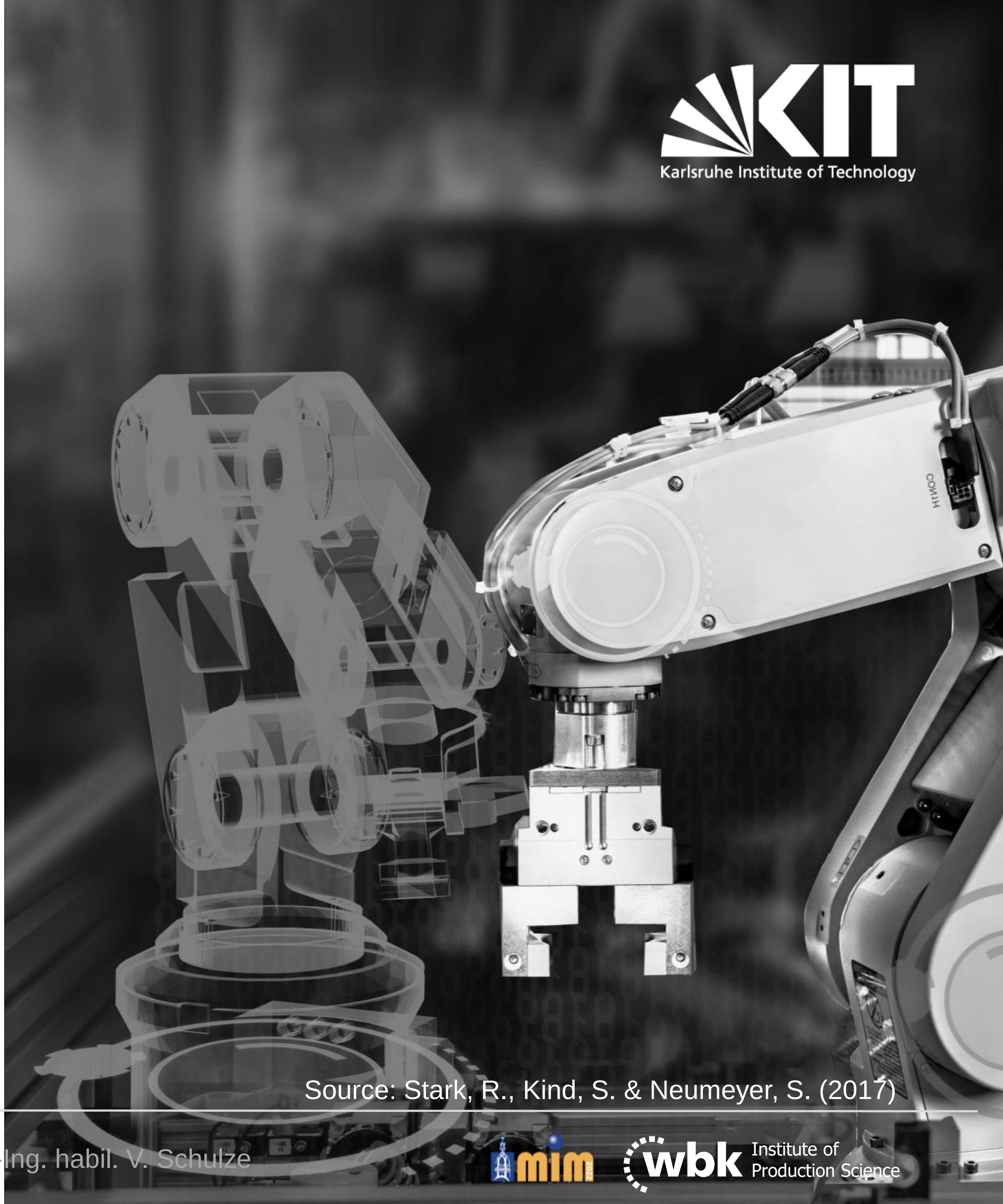
Industry 4.0 enables competitive production operations in the VUCA world. A **Digital Twin** unites and utilizes the enablers of Industry 4.0 and decreases uncertainty to operate efficiently in the VUCA world.

Source: siemens.com/BIM, forbes.com, Teh 2020, Jeet Kaur 2020

Digital Twin of Product and Production

Definition





Source: Stark, R., Kind, S. & Neumeyer, S. (2017)

Digital Twin of Product and Production

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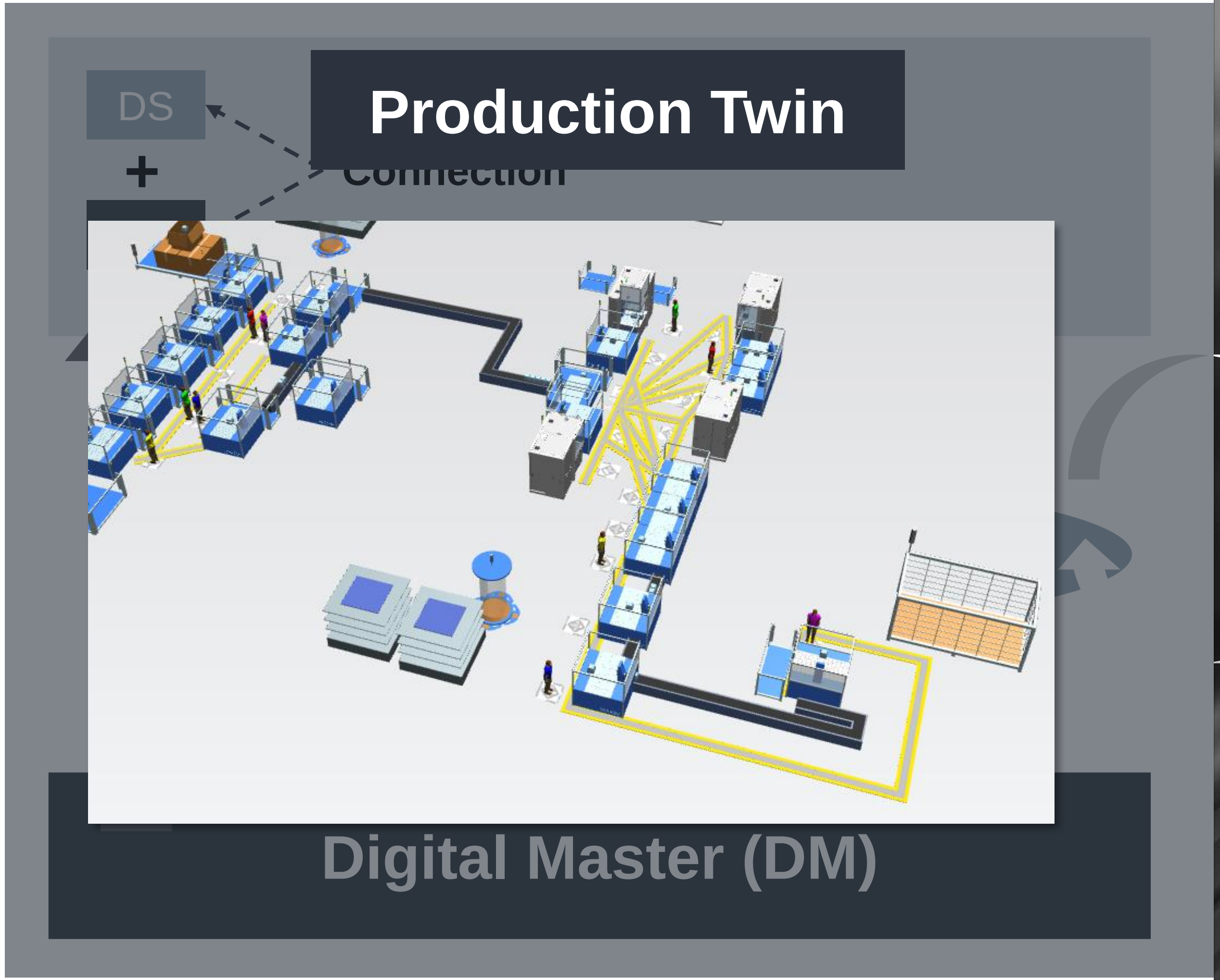

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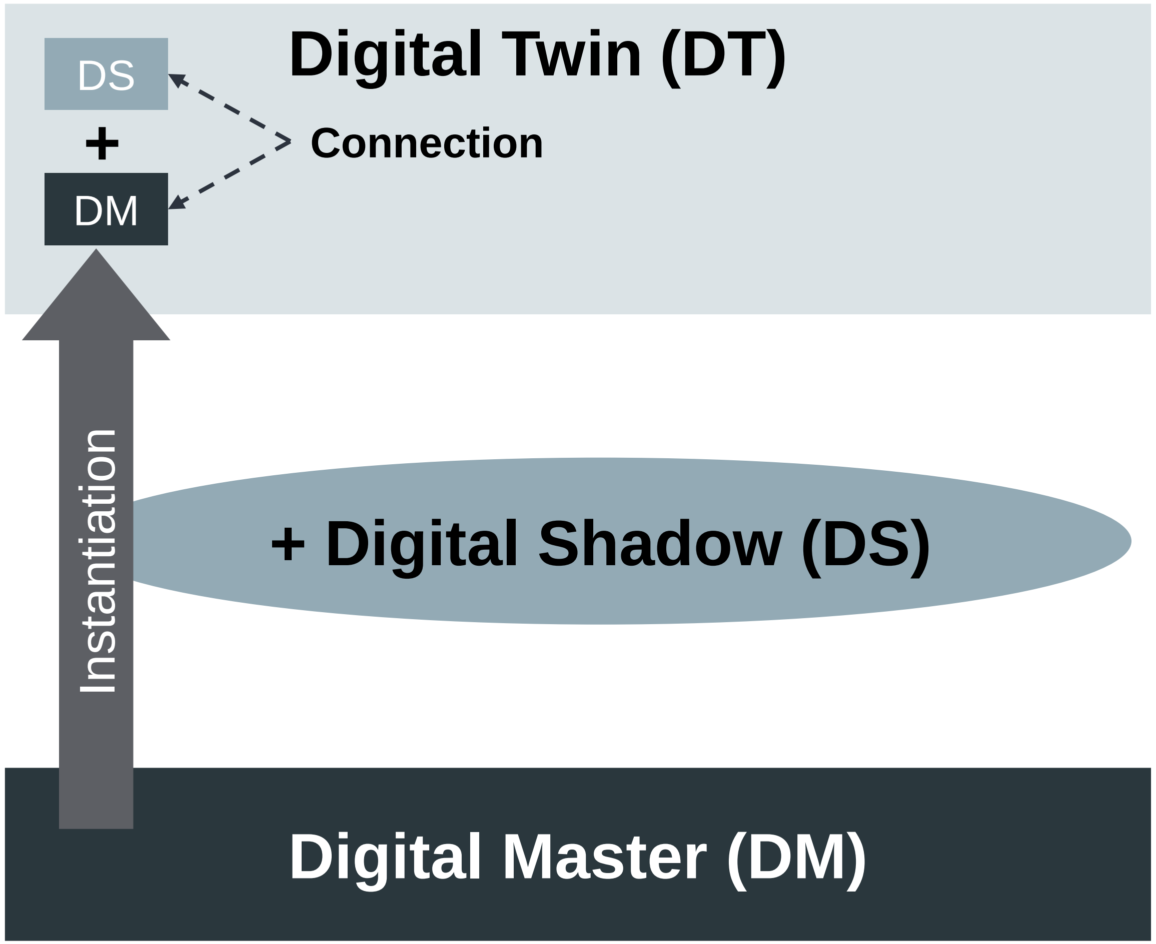
Digital Twin of product and production

Definition



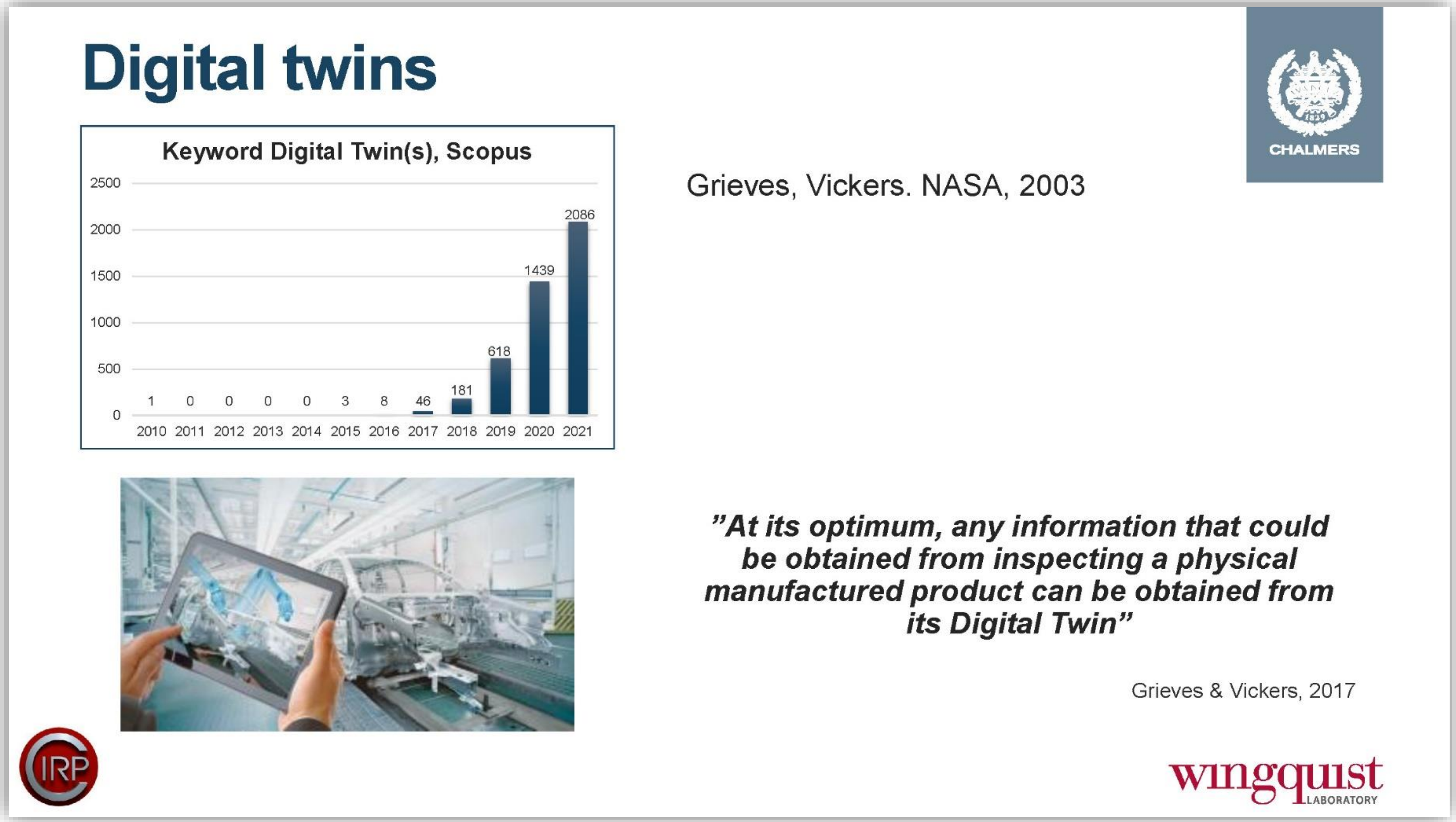
Real-time capability enables ad-hoc updating of the digital twin

Supplying product and process models with high quality data

Valid depiction of production as a starting point for analyses and forecasts

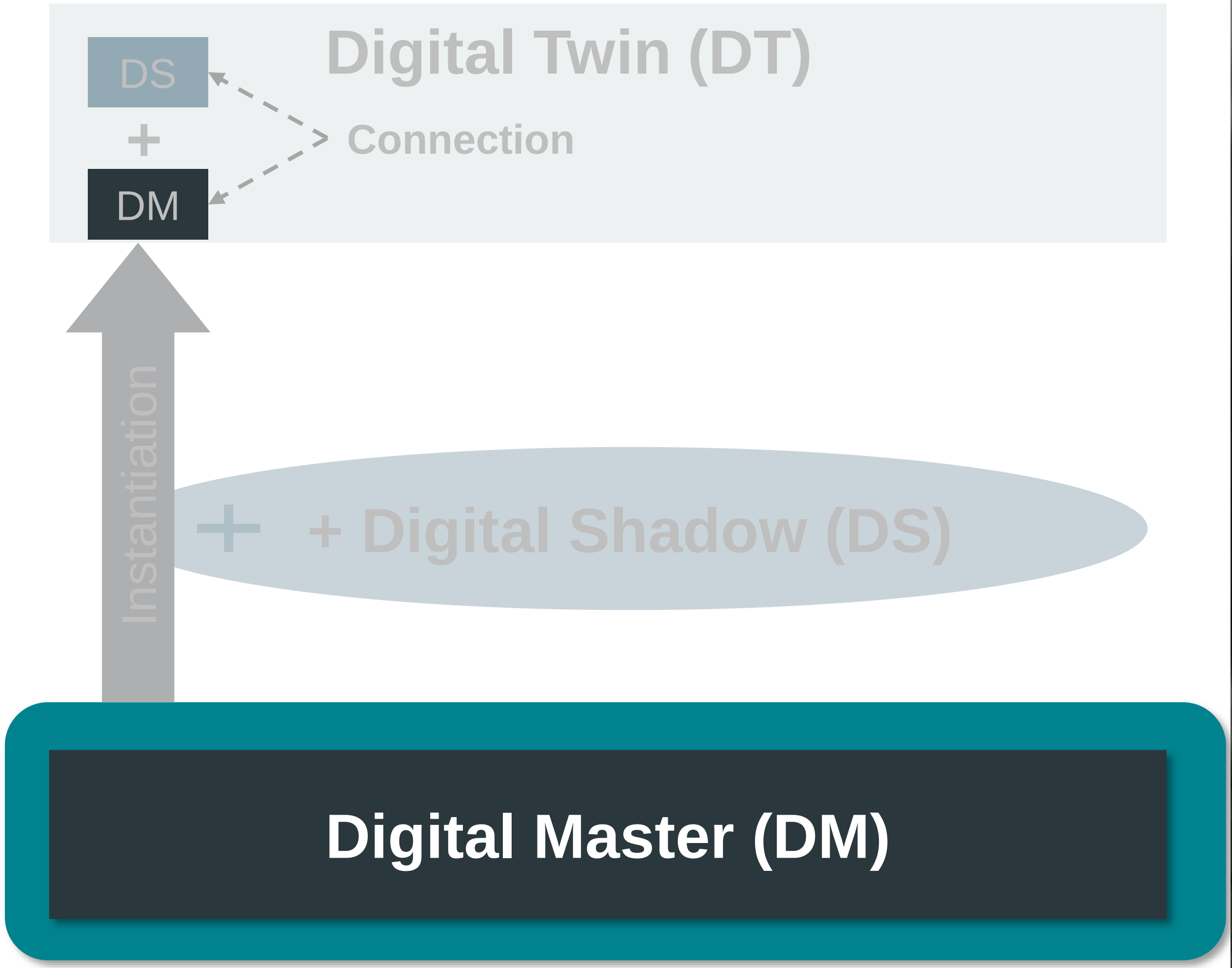
Source: Stark, R., Kind, S. & Neumeyer, S. (2017)

Retrospect:
Digital twin Keynote at CIRP CAT 2022 by Kristina Wärmefjord



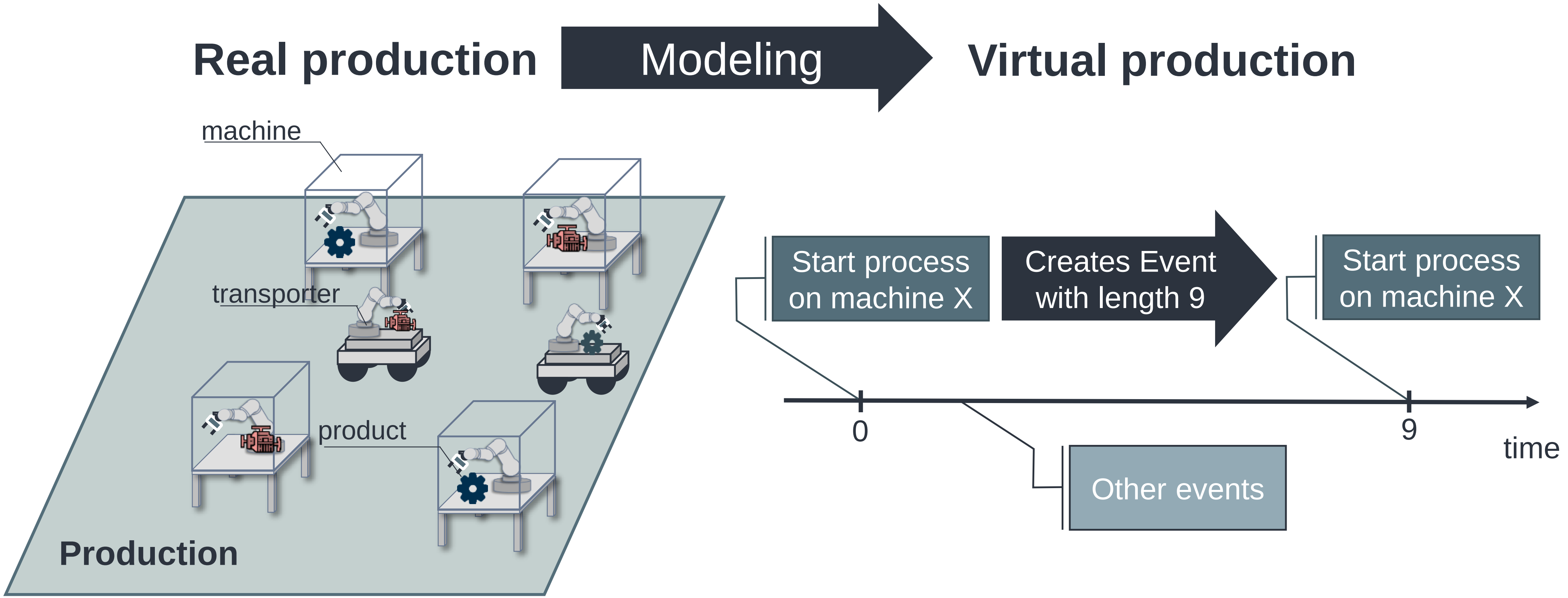
Digital Master for production system

Improve decision quality by enhanced digital models



Source: Stark, R., Kind, S. & Neumeyer, S. (2017)

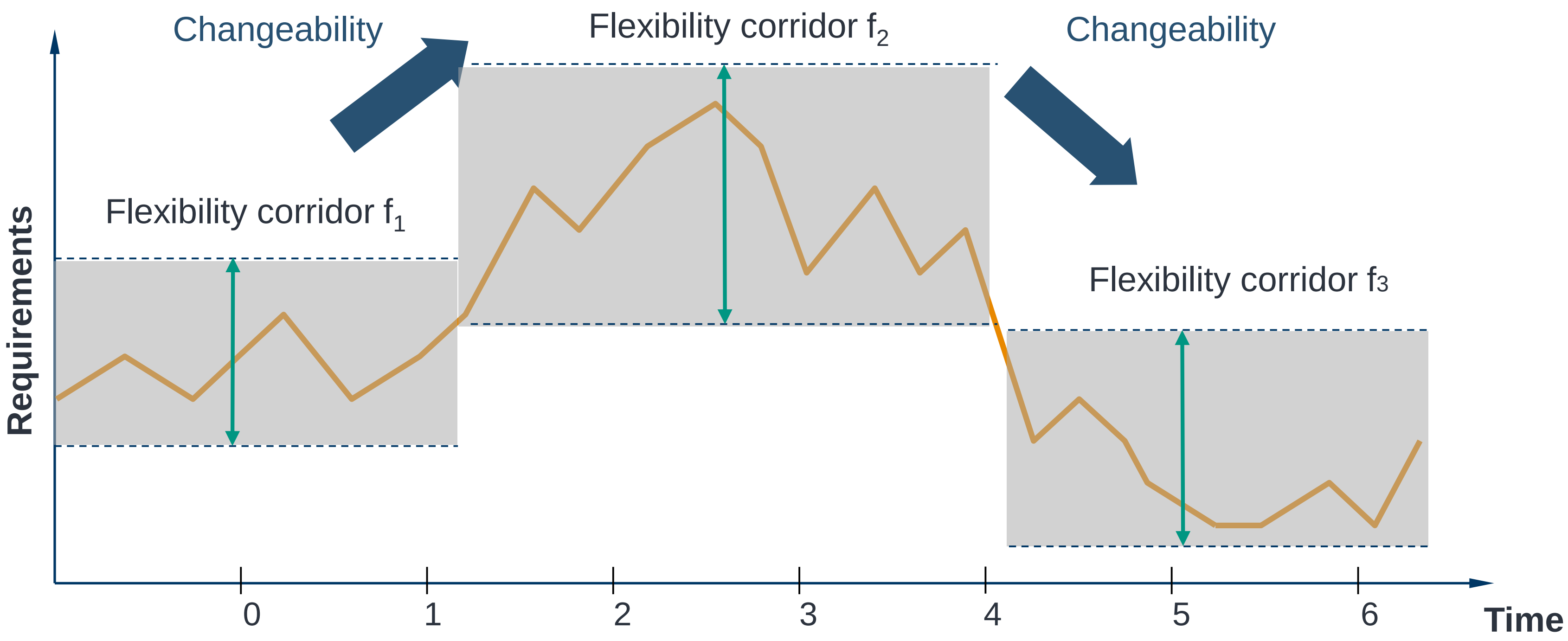
Discrete-event simulation (DES) as the basis for the digital master of a production system



Sophisticated simulation models allow for detailed and reliable foresight in production systems.
However, conventional simulation models are rigid in regard of expanding the digital master.

Ingenieure, V.D. VDI 3633 Simulation von Logistik-, Materialfluß- und Produktionssytemen; Beuth: Düsseldorf, Germany, 1996

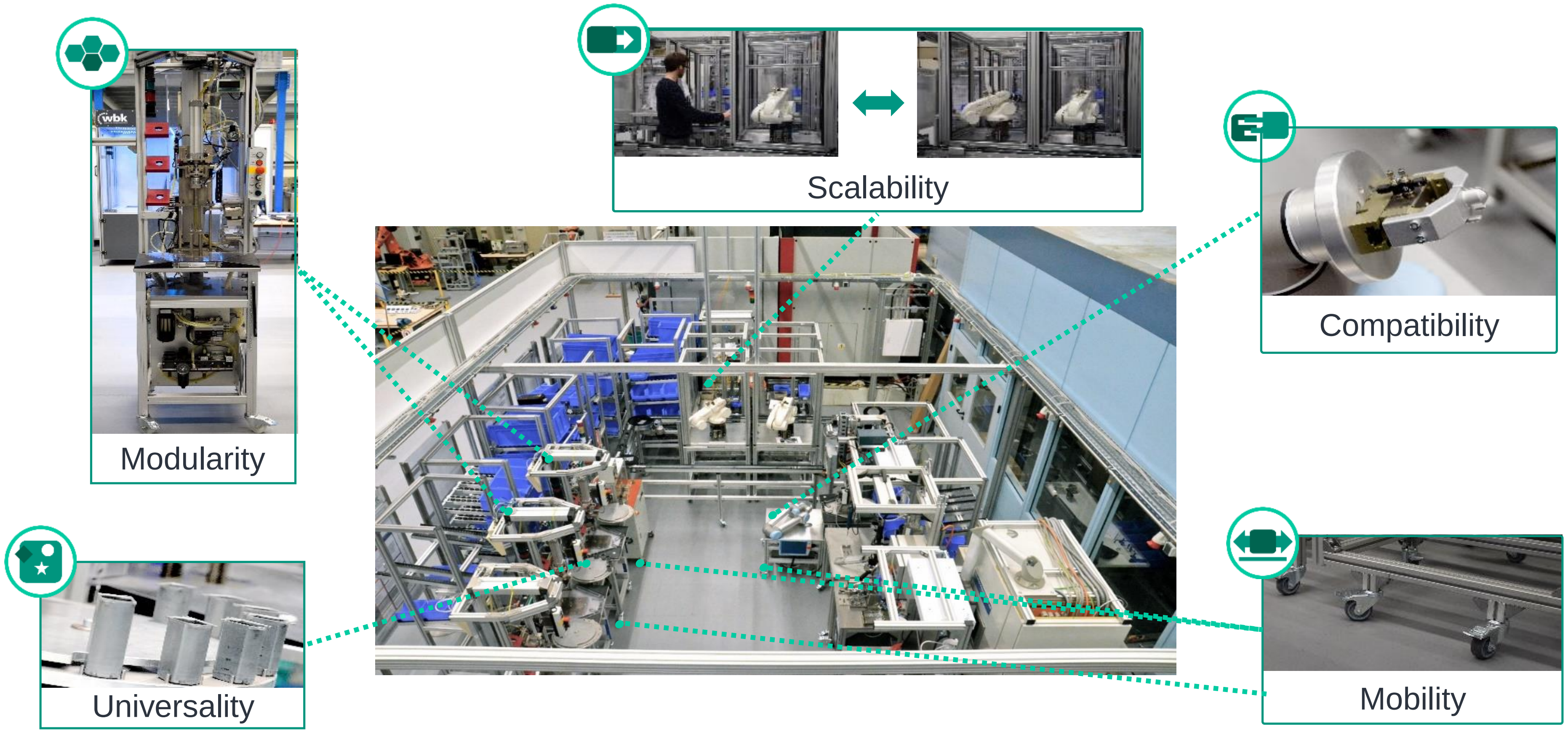
Flexibility and changeability in production



The trend of product individualization and ever-shorter product life cycles requires flexible and changeable production systems.

Source: IFA 14.788 | H.-P. Wiendahl, Zäh, Reinhardt

Flexibility and changeability in production

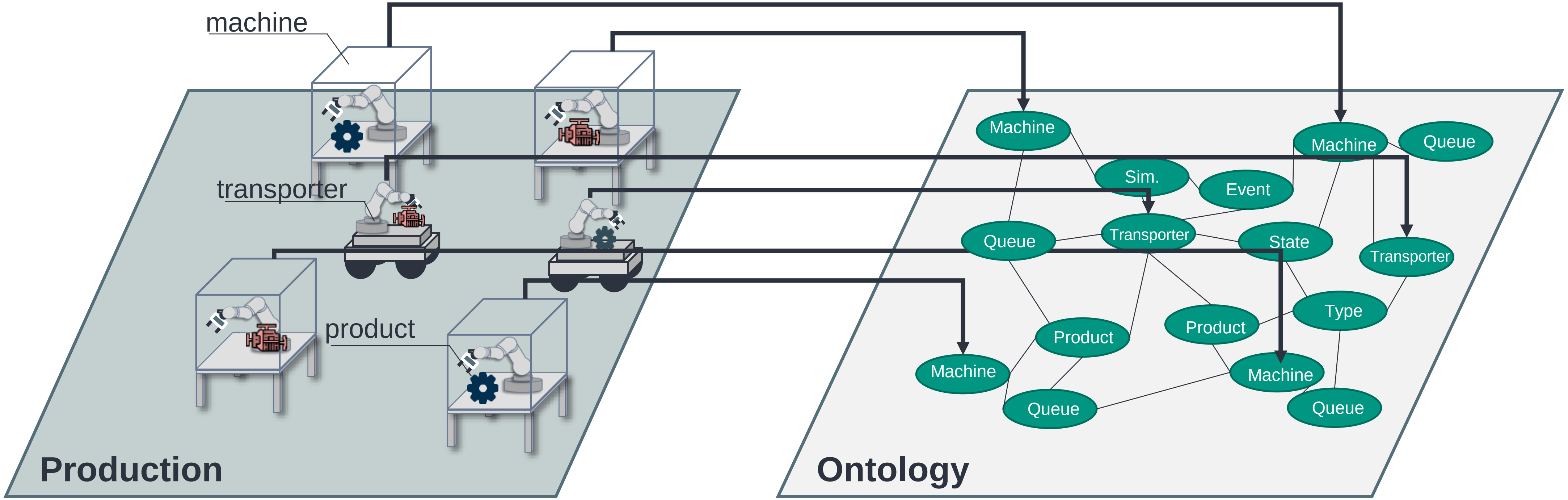


The trend of product individualization and ever-shorter product life cycles requires flexible and changeable production systems.

Ontology enhanced digital master

Semantics are helpful to further improve versatility

Ontology as a model of state



The ontology allows to model real production systems by mapping the assets of the production system to the simulation in an abstract way. This results in a higher flexibility of the digital master.

May, Kiefer, Kuhnle, Lanza (2022): Ontology-based Production Simulation with OntologySim

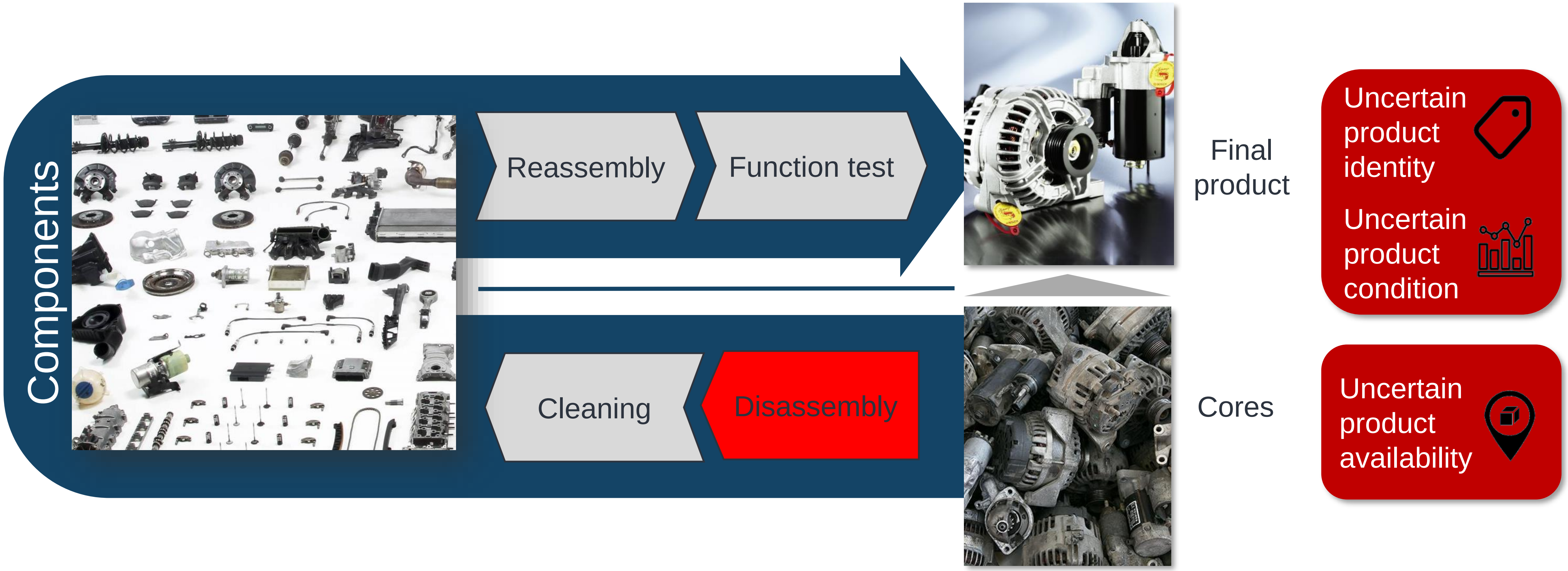
Use case: Agil production for circular manufacturing

Remanufacturing is characterized by a high degree of uncertainty

Source: Borg, Bosch

Use case: Agil production for circular manufacturing

Remanufacturing process chain



Especially product disassembly is impeded by uncertain product specifications. Production planning is either ineffective or inefficient due to a high number of anomalies and unpredictable events.

Source: C-ECO, Bosch, bz-berlin

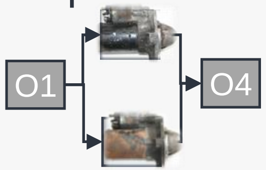
Use case: Agil production for circular manufacturing

Definition of an agile remanufacturing system

Uncertain type and quantity of used products [1]

Diverging material flow

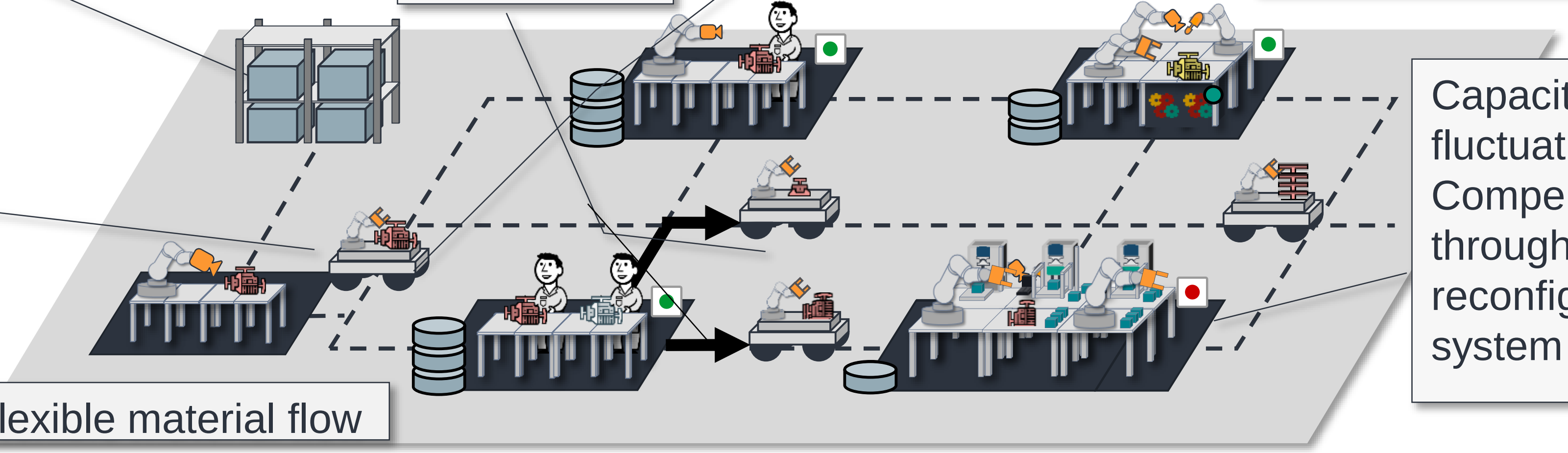
Alternative sequence of operations



Product condition influences:

- Operation times
- Product routings
- **Regeneration rates**
- Required production capacity

Detailed inspection immediately before disassembly



Flexible material flow

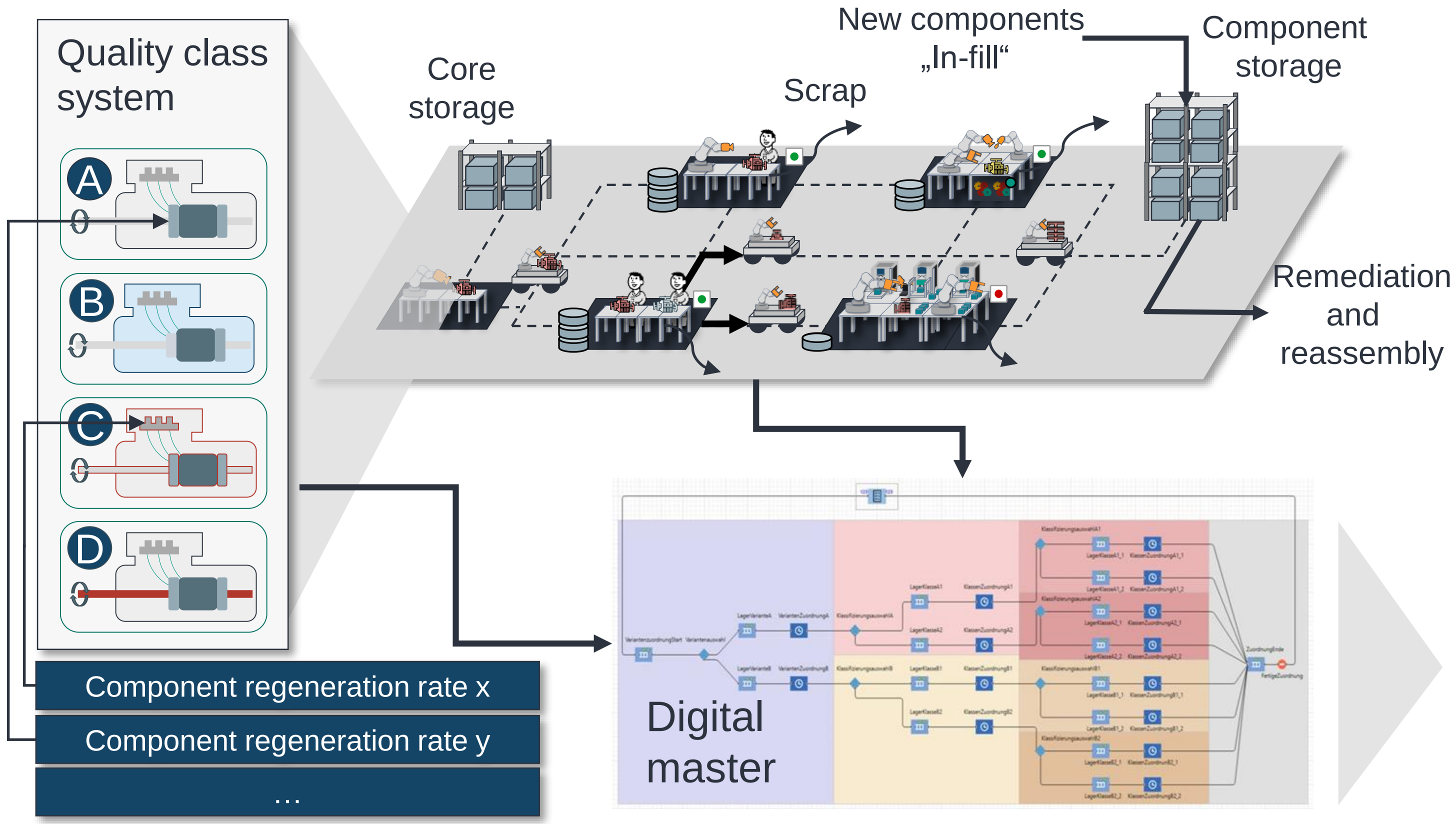
Capacity demand fluctuations - Compensation through reconfiguration at system and cell level

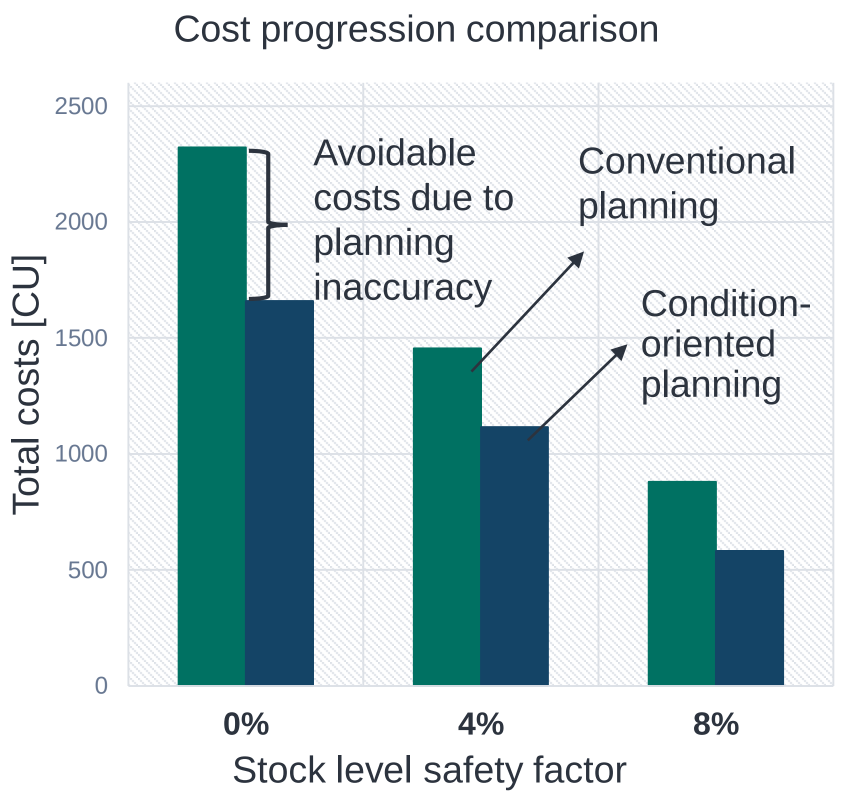
Many complexities within the disassembly system, such as the condition of discarded products, are mapped in a digital master to overcome uncertainty and improve production planning and control.

Source: [1] Inderfurth & Langella (2006), agiprobot.de

Use case: Agil production for circular manufacturing

Improving material requirements planning in remanufacturing



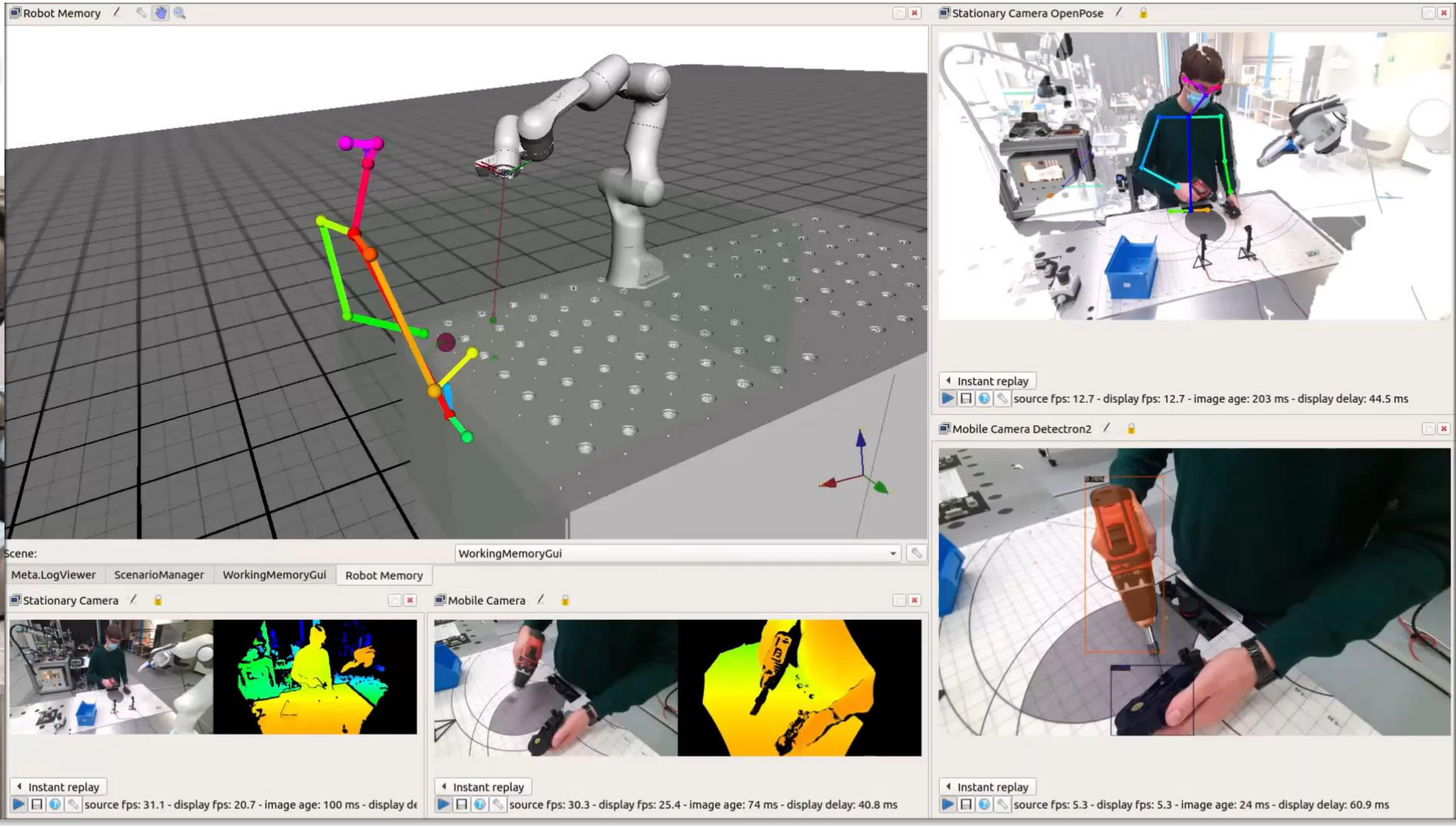


Simulation-based material requirements planning based on a digital master respecting the condition of used products increases planning accuracy and decreases stock level at high delivery reliability.

Use case: Agil production for circular manufacturing

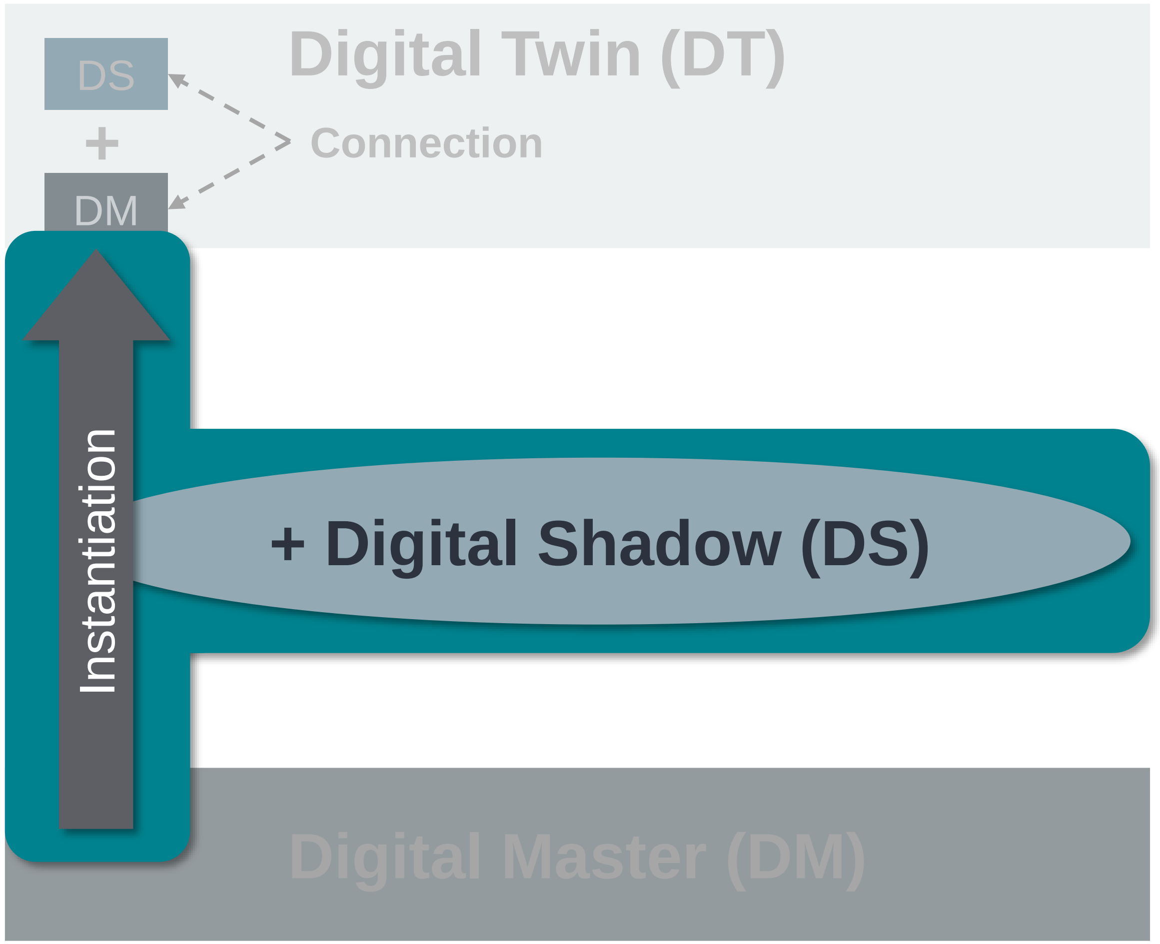
Implementation of the real production system

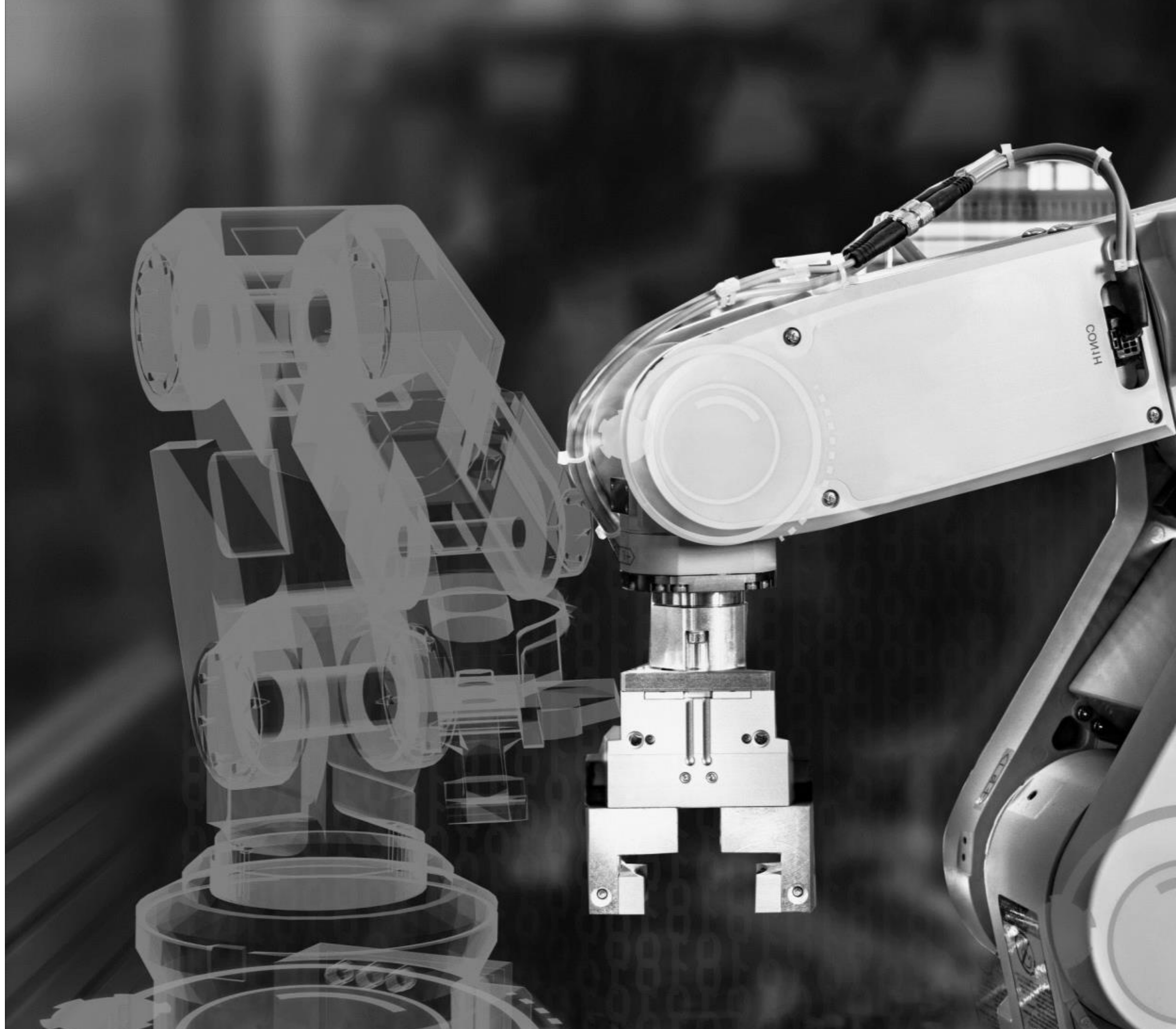
Focus: Disassembly of electrical drives



Digital Shadow of production system

Supporting acceptance by automatic instantiation

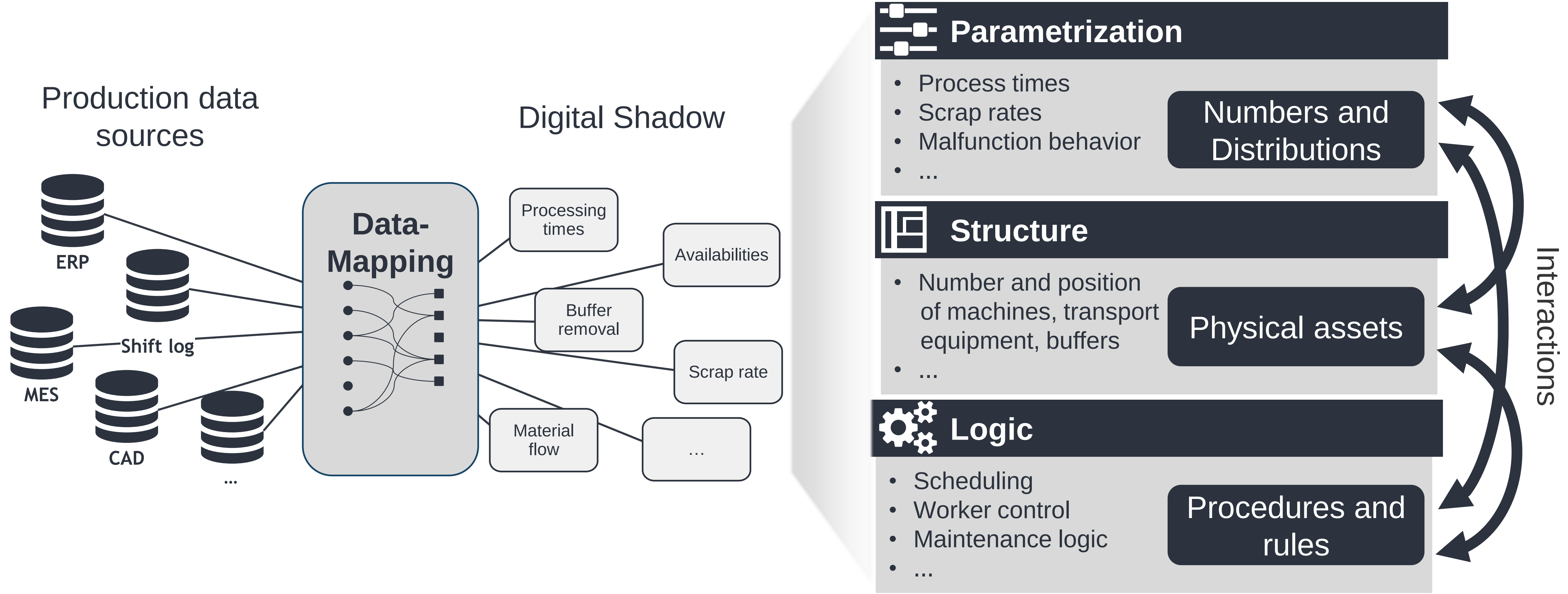




Source: Stark, R., Kind, S. & Neumeyer, S. (2017)

Information systems & data sources for the Digital Shadow

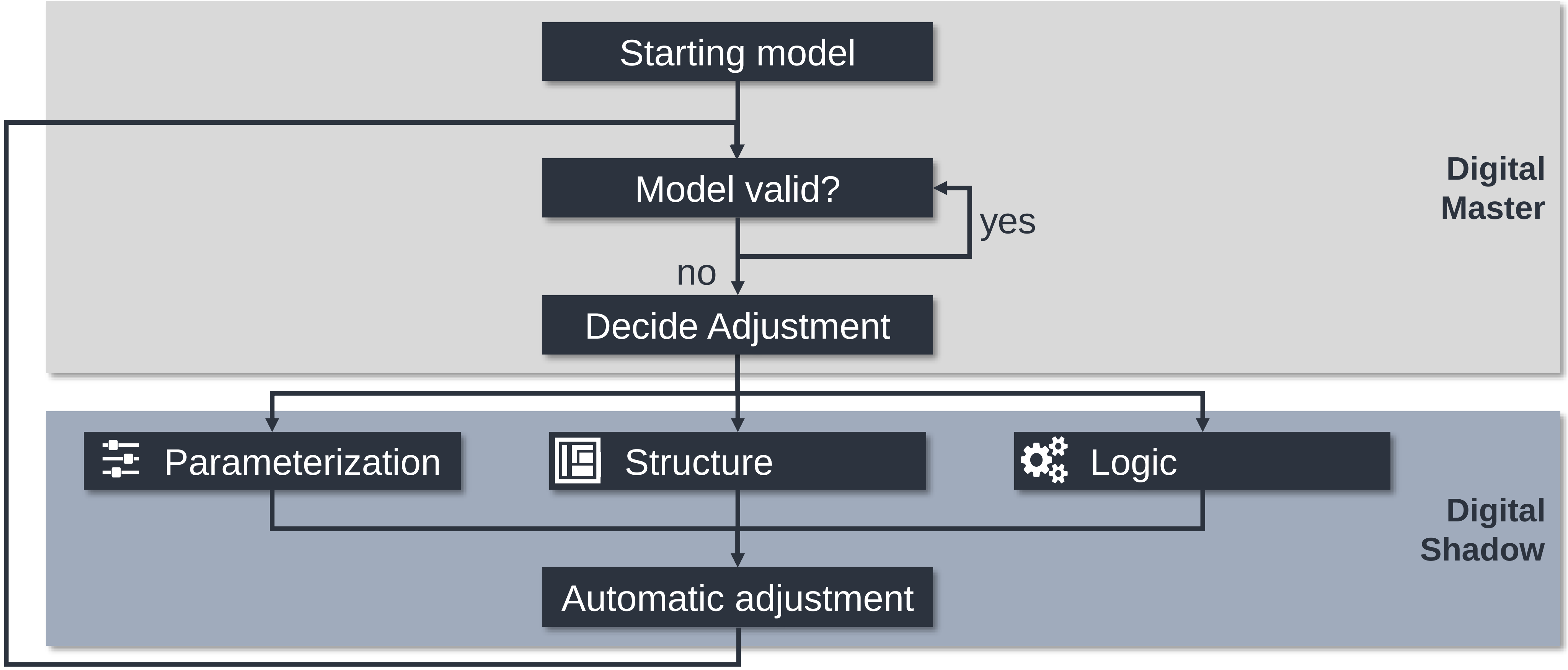
Track and link data for Digital Twins



By connecting heterogenous data sources and digital shadow with a standardized adapter, the interoperability can be guaranteed.

Source: Leonard Overbeck (2021),

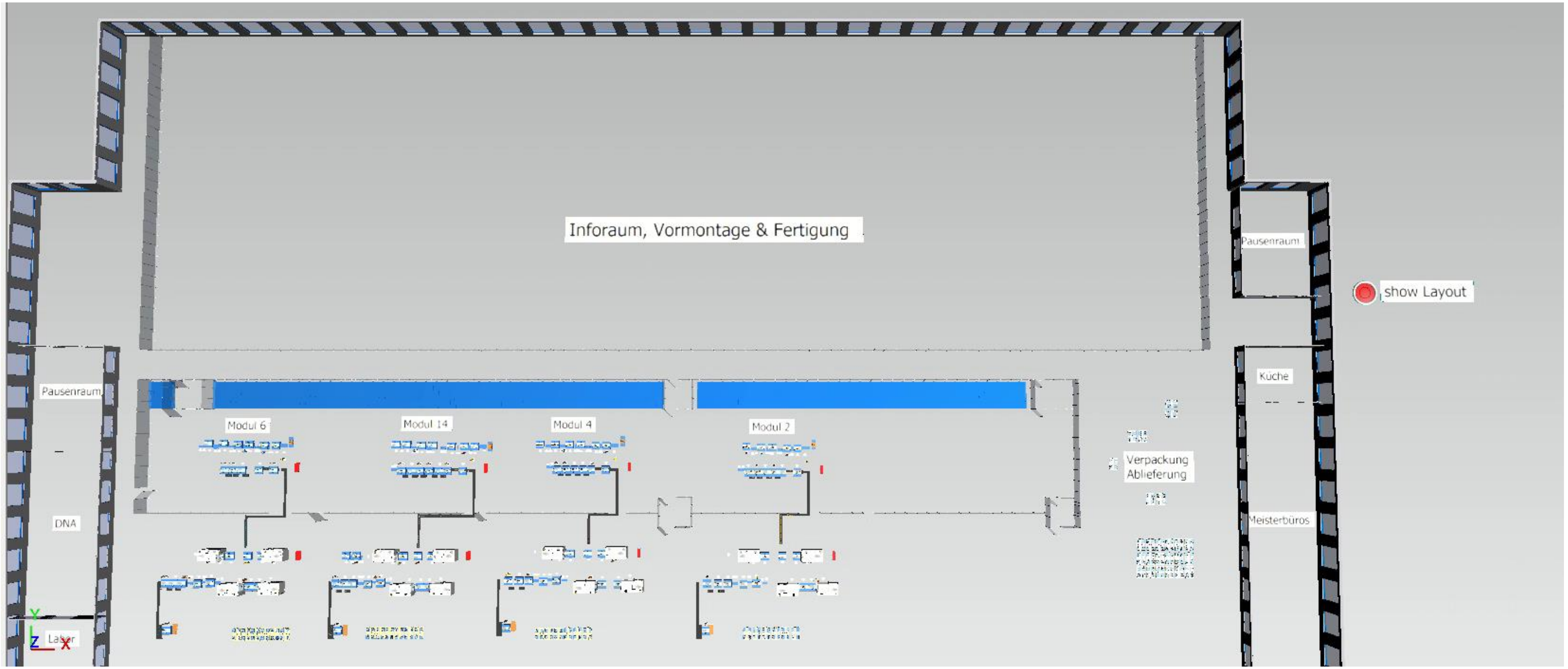
Updating and validating the digital shadow of the production system with real production data



By following an iterative adaption approach with consideration of new data, it can be guaranteed that the digital shadow represents the current state of the real production system.

Source: Leonard Overbeck (2021),

Example of a simulation model of a production system based on real production data



Source: Leonard Overbeck (2021), Software: Tecnomatix Plant Simulation

Evaluation of simulation results with historic data shows a valid representation of the real system

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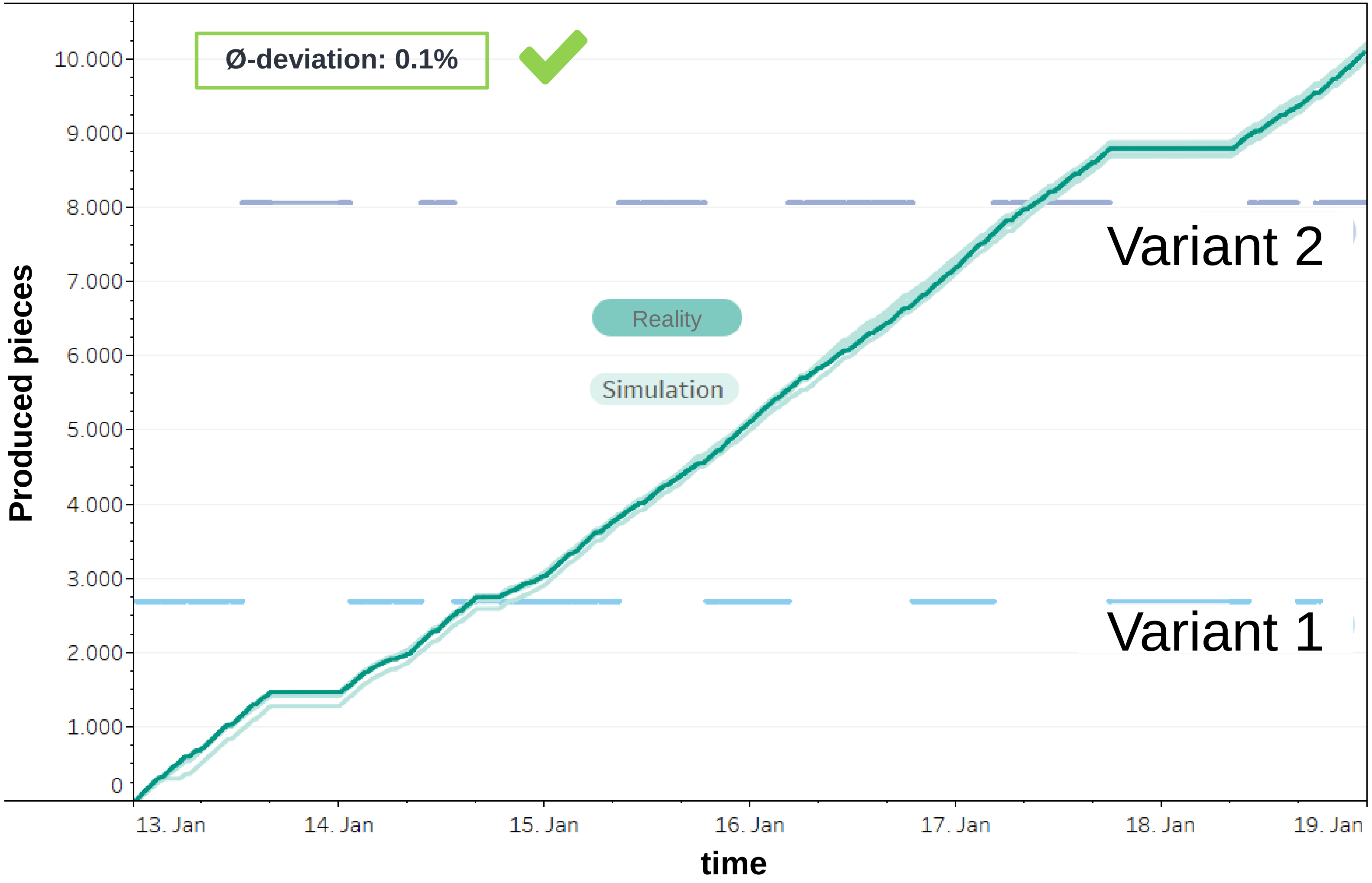
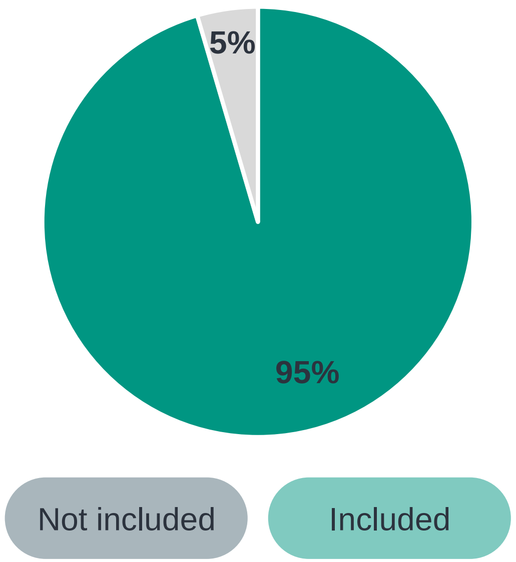


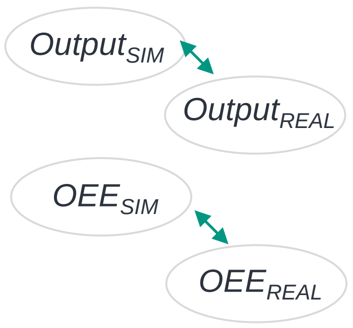
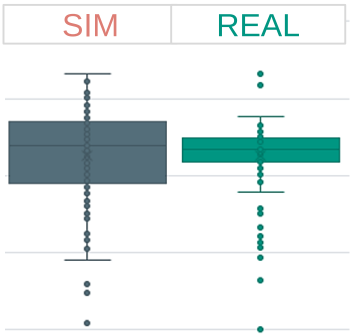
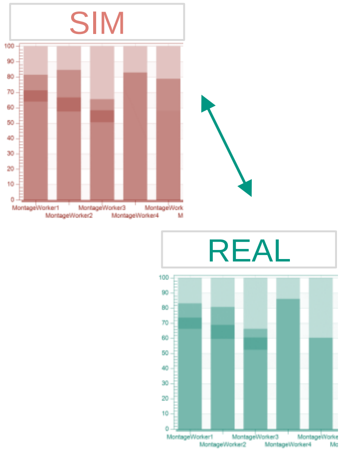
Production volume represented by a variety of variants

(Reference: Produced pieces from August '19 to April '20)



Source: Leonard Overbeck (2021),

Metrics to validate the digital shadow with the real production

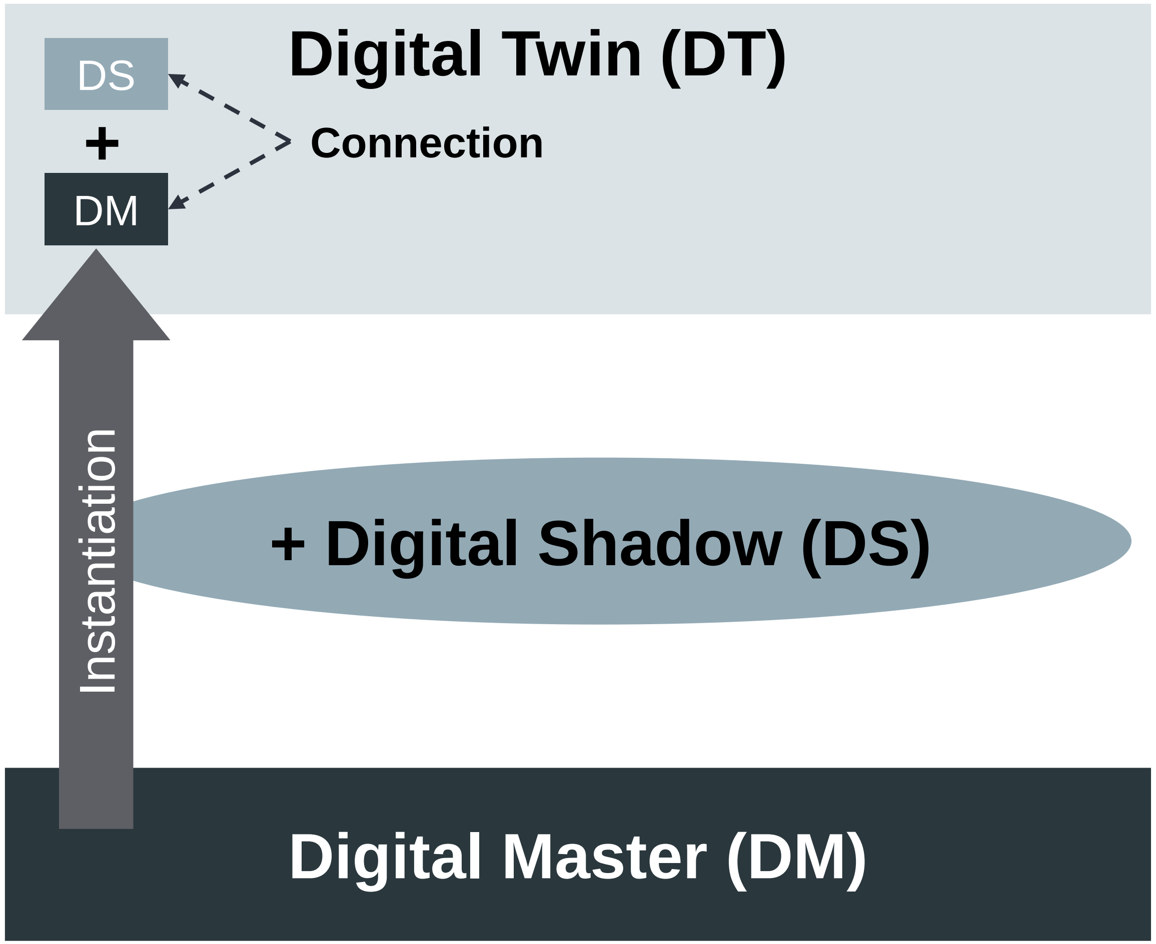
Metric	Total Output and OEE	Dynamics	Distributions	Resource utilization
Purpose	Mapping the core function of the production system	Dynamics of the model in the period under consideration	Stability of the system in reality and simulation	Internal processes in the system
Example				

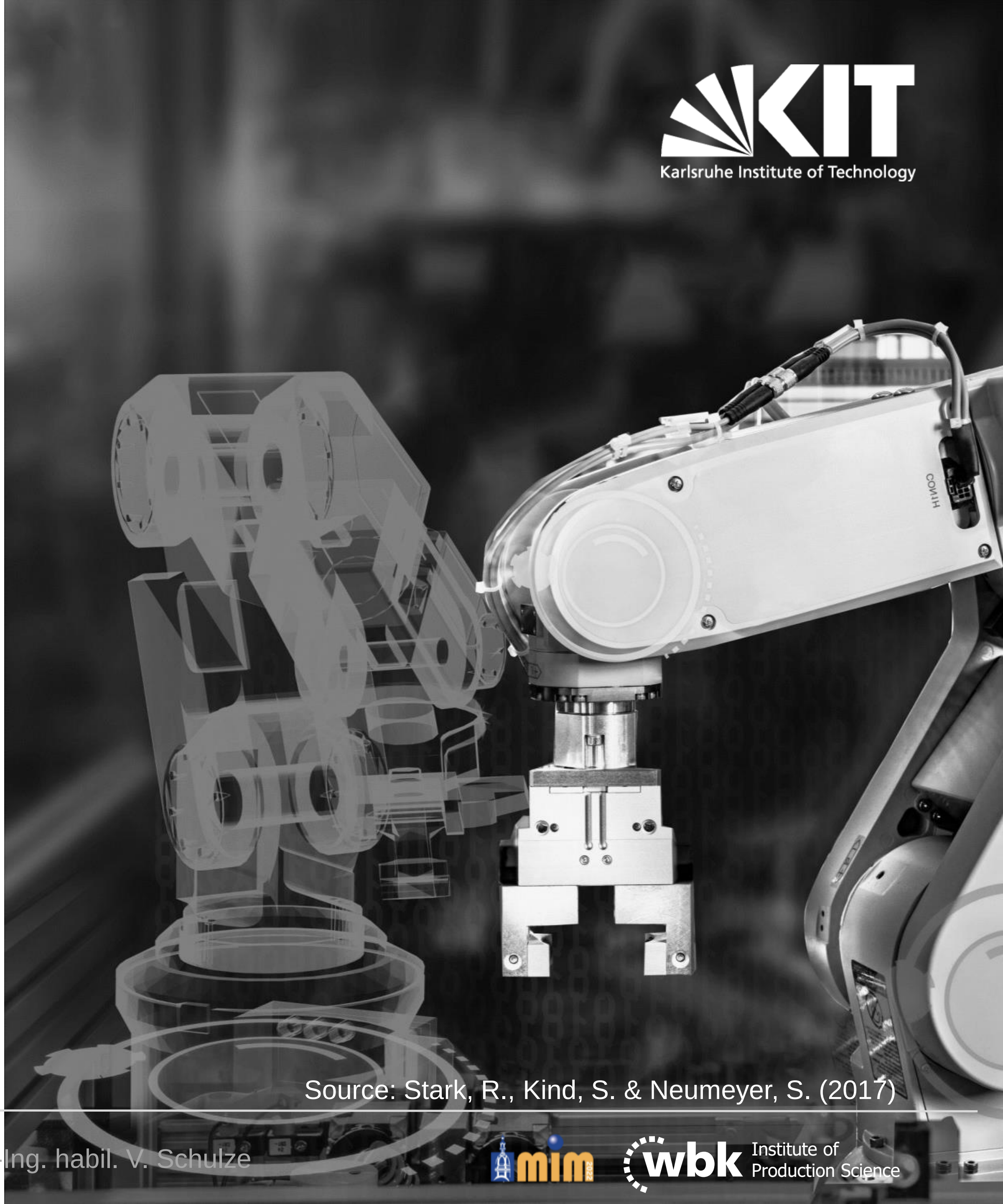
By comparing the simulation model and reality with respect to metrics, the validity of the digital shadow can be determined.

Source: Leonard Overbeck (2021),

Digital Twin

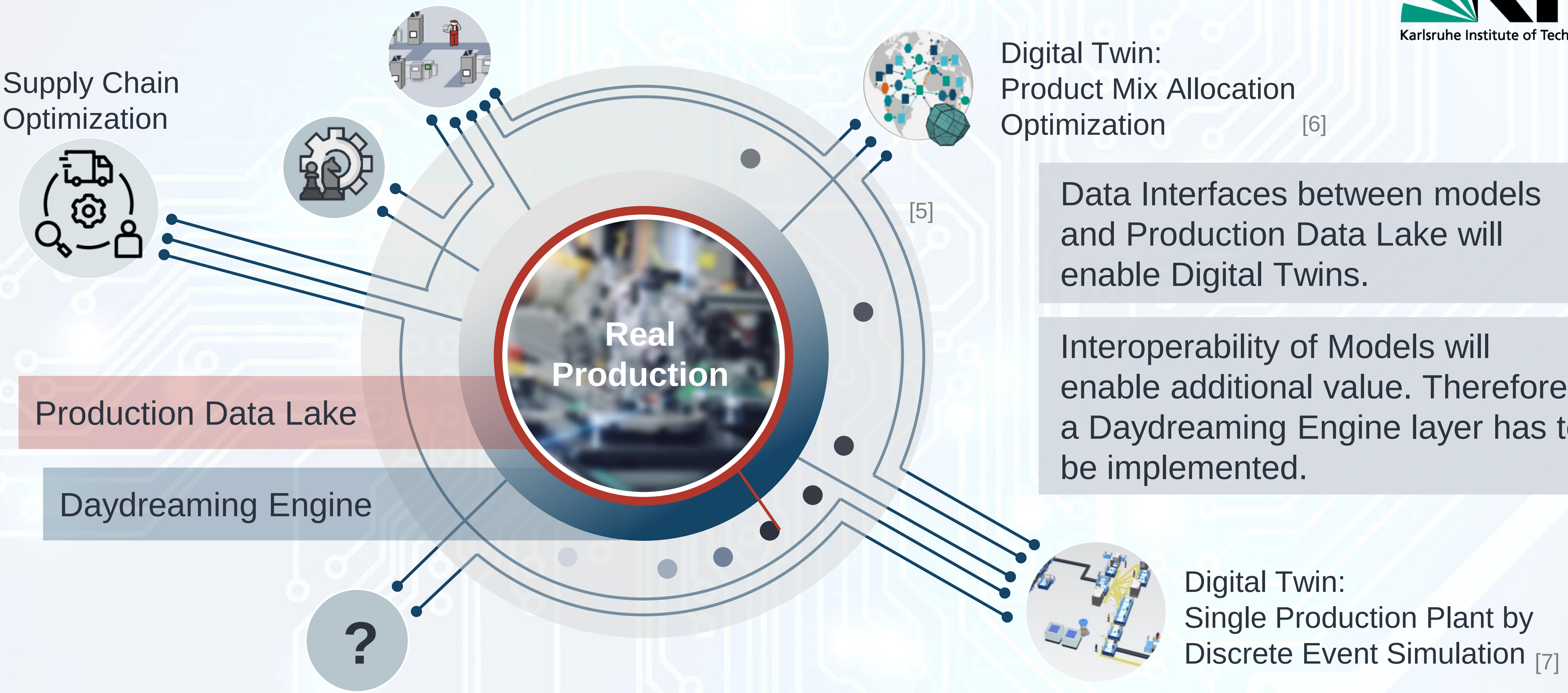
Vision for the future





Source: Stark, R., Kind, S. & Neumeyer, S. (2017)

Outlook: Daydreaming Engine



Data Interfaces between models and Production Data Lake will enable Digital Twins.

Interoperability of Models will enable additional value. Therefore, a Daydreaming Engine layer has to be implemented.

Connecting models across perspectives and levels enabling changeability of product an production

Source: [5] based on CIRP Keynote 2022-Nassehi et al., [6] Brützel et al. (2021); [7] Benfer et al. (2021);

Vision of the digital twin for changeable production systems in the future

Conclusion

Automated Modeling

- Automatic Generation
- Continuous Synchronization
- High validity / accuracy of the model

Decision support

- Planning and assessment of reconfigurations
- Integration of planning and control tools

Multiple Models

- Simultaneous use of different modeling techniques
- All models rely on the same data and can be used synergistically

Faster deployment

- Virtual commissioning
- Automated deployment of changes to the production

Thank you for your attention!

10th IFAC Conference on Manufacturing Modelling, Management and Control

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Sources

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