Review of models for large scale manufacturing Networks

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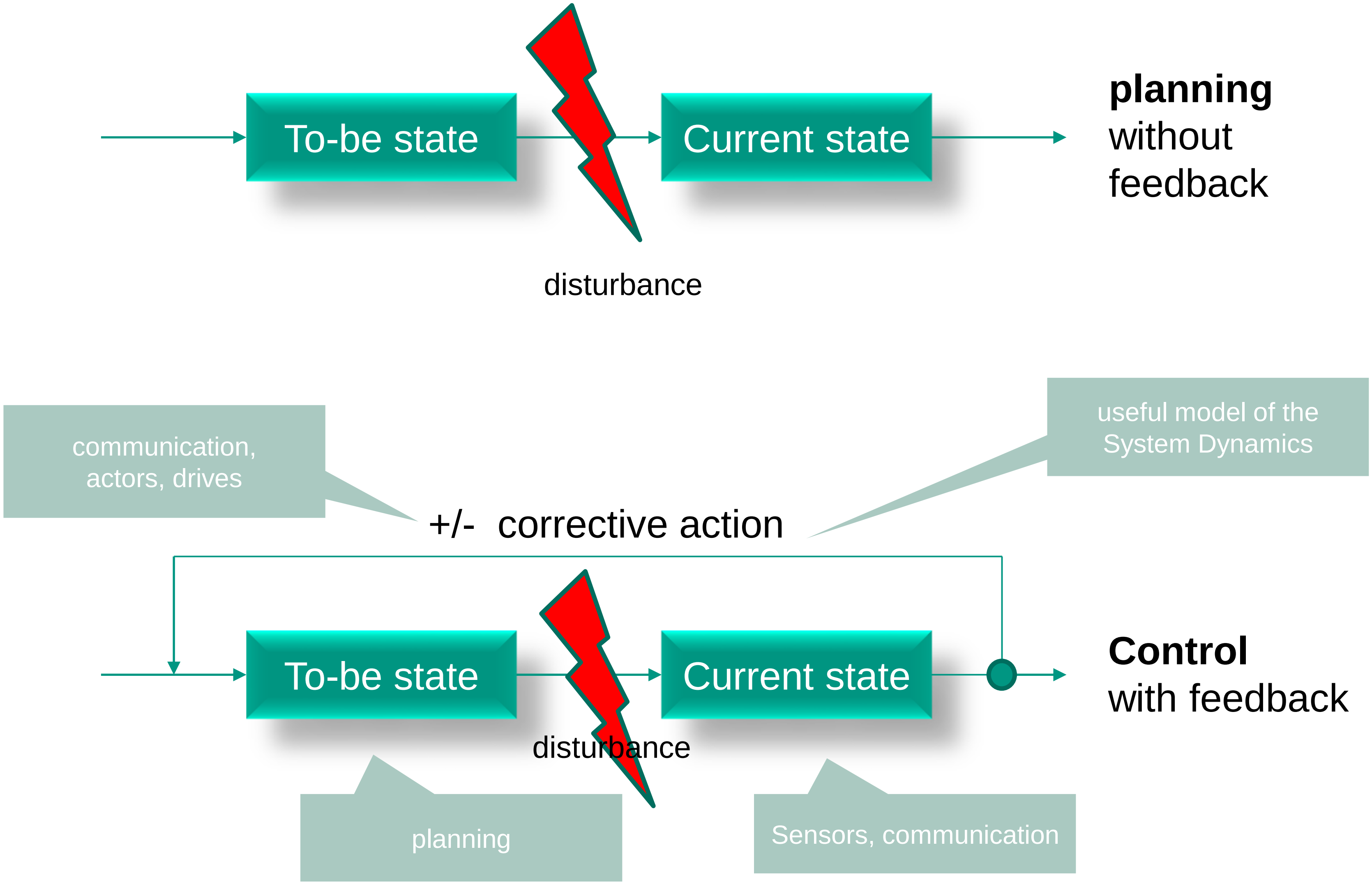
Outline Presentation

- **The Research Idea –**
  - **Controlling Supply Networks as Cyber-physical Systems**
  - **Cyber-Physical Systems – Definition and an Example**
- The Research Project *Productive4.0*
  - Positioning of the Project
  - Scope of the project
  - Project Structure
- The Methods and Tools of WP4 & WP5 of *Productive4.0*
- Literature Review
- Conclusion

Real-time Control of any Physical System



Differences between Factories and Airplanes

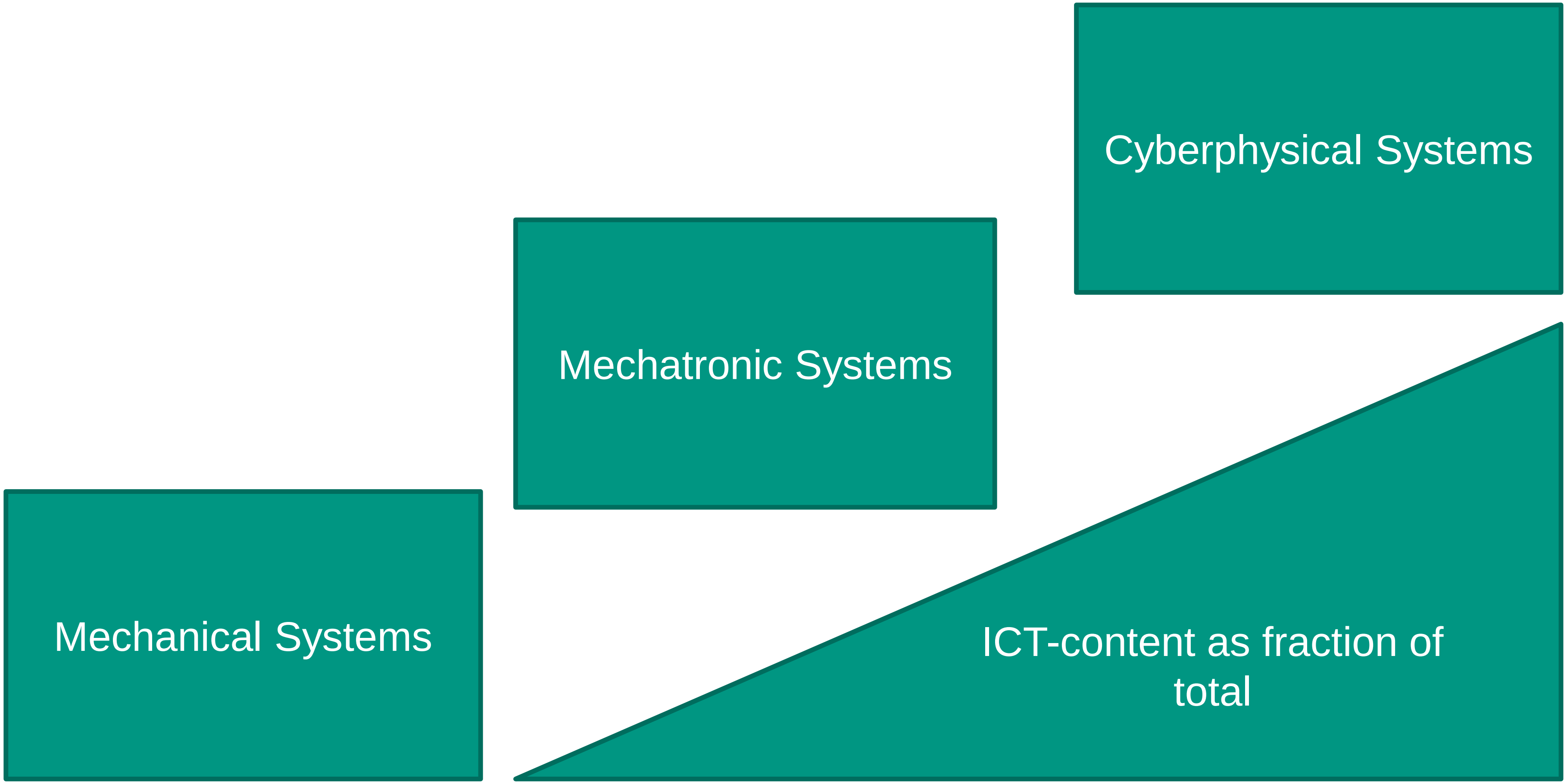
- Control model available
- Continuous state, continuous corrective actions
- High frequency of small corrections
- Most planes inherently stable, stability a key factor
- <u>One</u> model

Airbus A320neo (airbus.com)

- Control model missing
- discrete state, discrete corrective actions
- No defined frequency of corrective actions, control frequency rather low
- Stability issues not known
- Multi-level model (if at all)

Aerial view of the Bosch semiconductor plants Reutlingen (kka-online.de)

What are Cyberphysical Systems



Cyberphysical Systems: Background

- Initiative of National Science Foundation (USA) 2006
- **Cyber**: computer based, digital control and communication

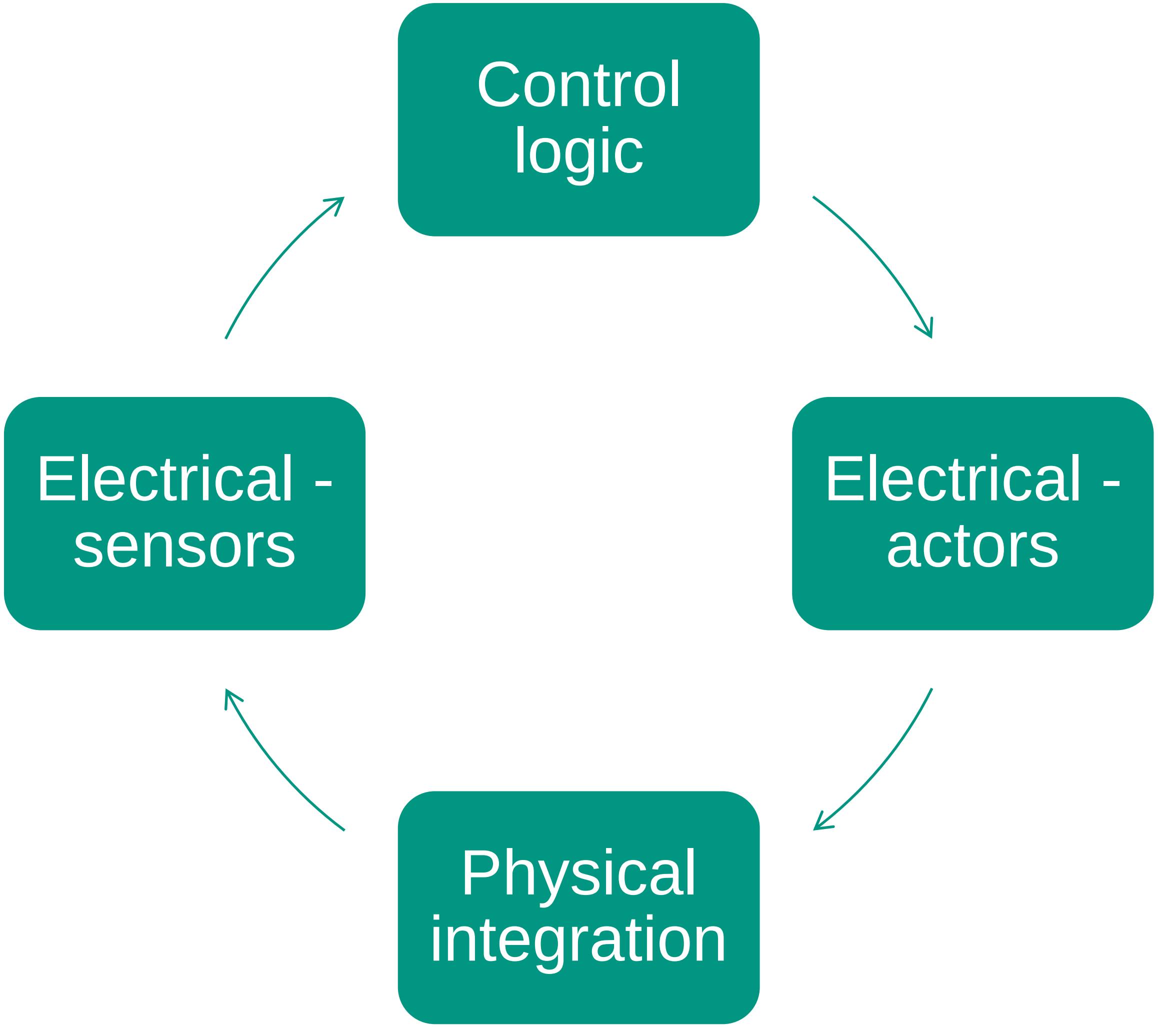
- **Physisch**: artificial or natural systems, underlying the laws of physics and working in continuous real time

- **Cyberphysical System**: autonomous control of physical systems based on digital, autonomous „comprehension“ of the system and it‘s environment

Why do we need CPS?

- A simple example from Material Handling

Reconfiguration of todays material handling systems needs changes in several levels



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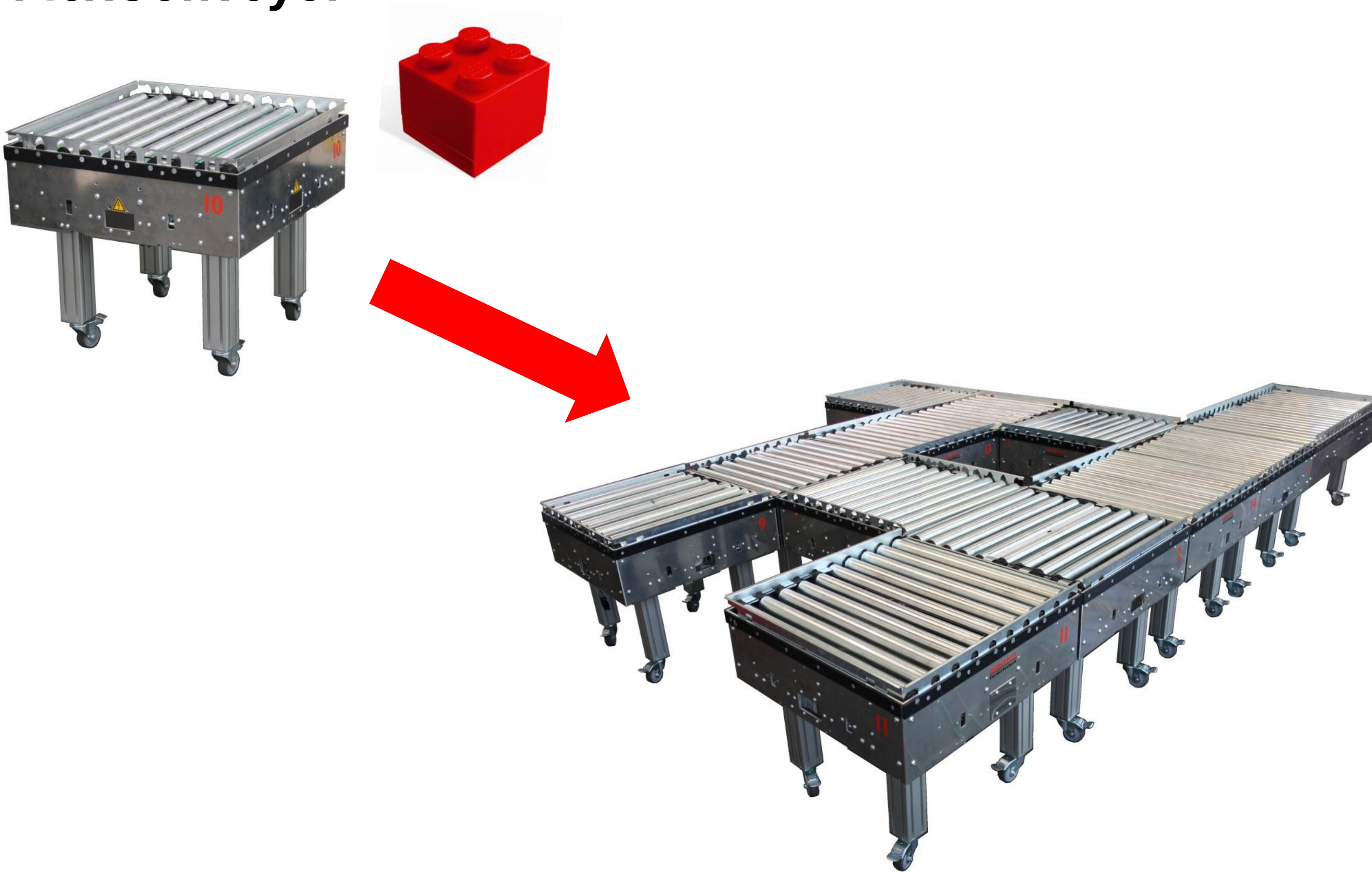
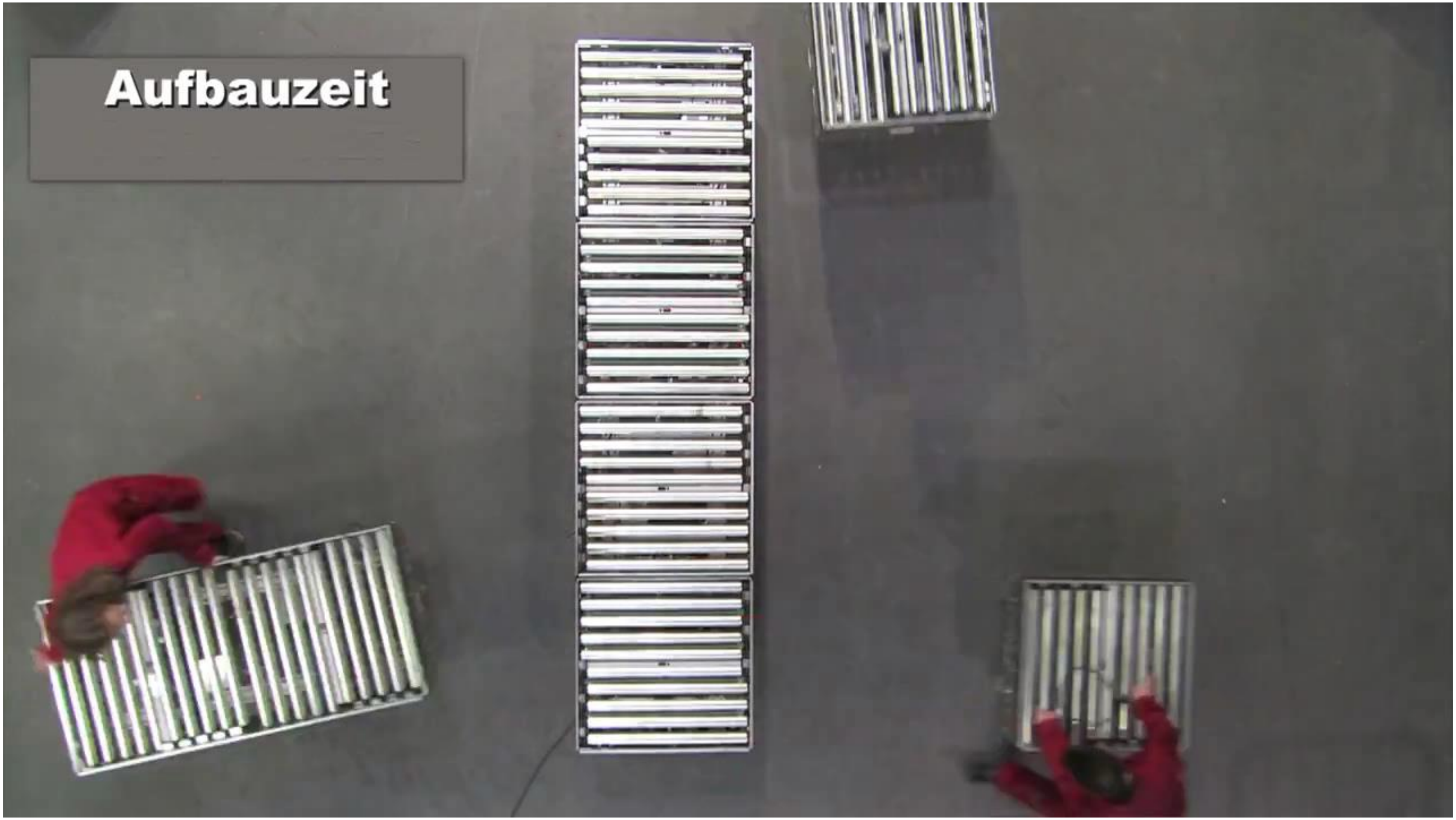
FlexConveyor

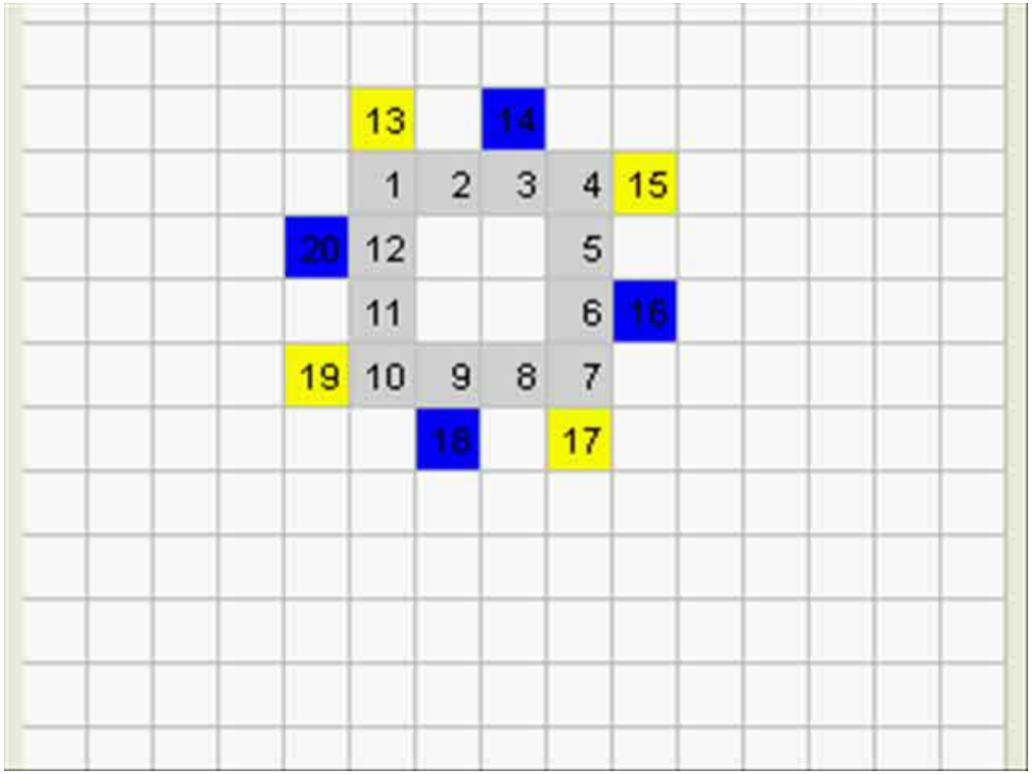


IFL

Flexconveyor – Assembly and Modification



Emerging Behaviour



GridStore

Characteristics Flexconveyor as a CPS

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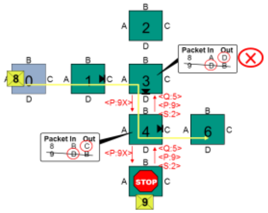
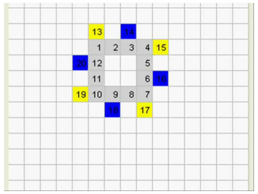
- Cyber:
  - Local Control can get enough information which is necessary to „understand“ the state of the system and its environment
  - Clear control system – „to be state“ clearly defined, „is-state“ clearly defined
  - There is always an action to get the system closer to it‘s to be state
  - Can make all necessary decisions
- Physical:
  - System is able to move real stuff
  - Is able to execute all the decisions
  - Provides cyber-part with sufficient feed back of real situation





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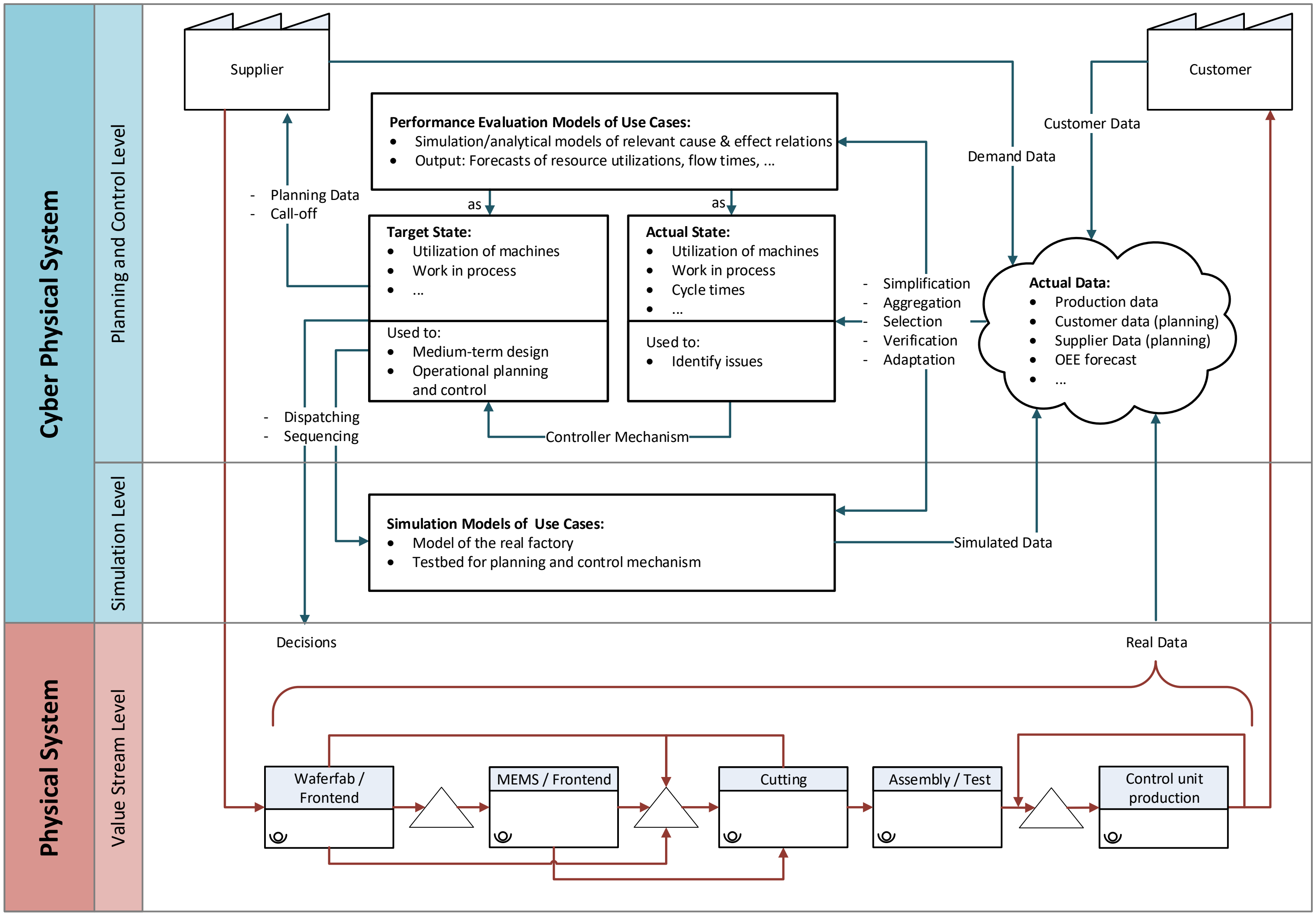
The Research Idea: Semiconductor Production Systems as Cyber Physical Systems

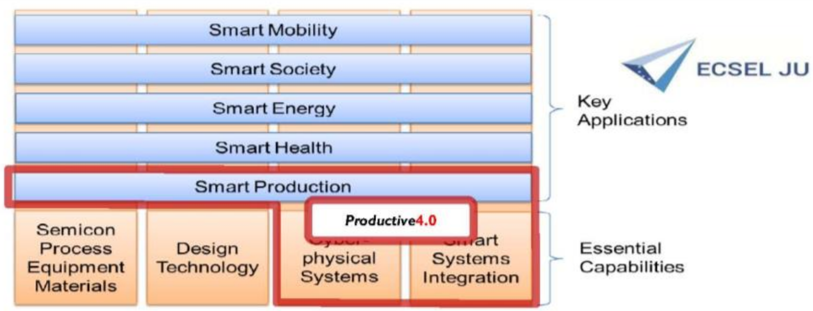


The Research Project *Productive4.0*

- Positioning of the Project

EC Horizon2020

ECSEL Electronic Components and Systems for European Leadership

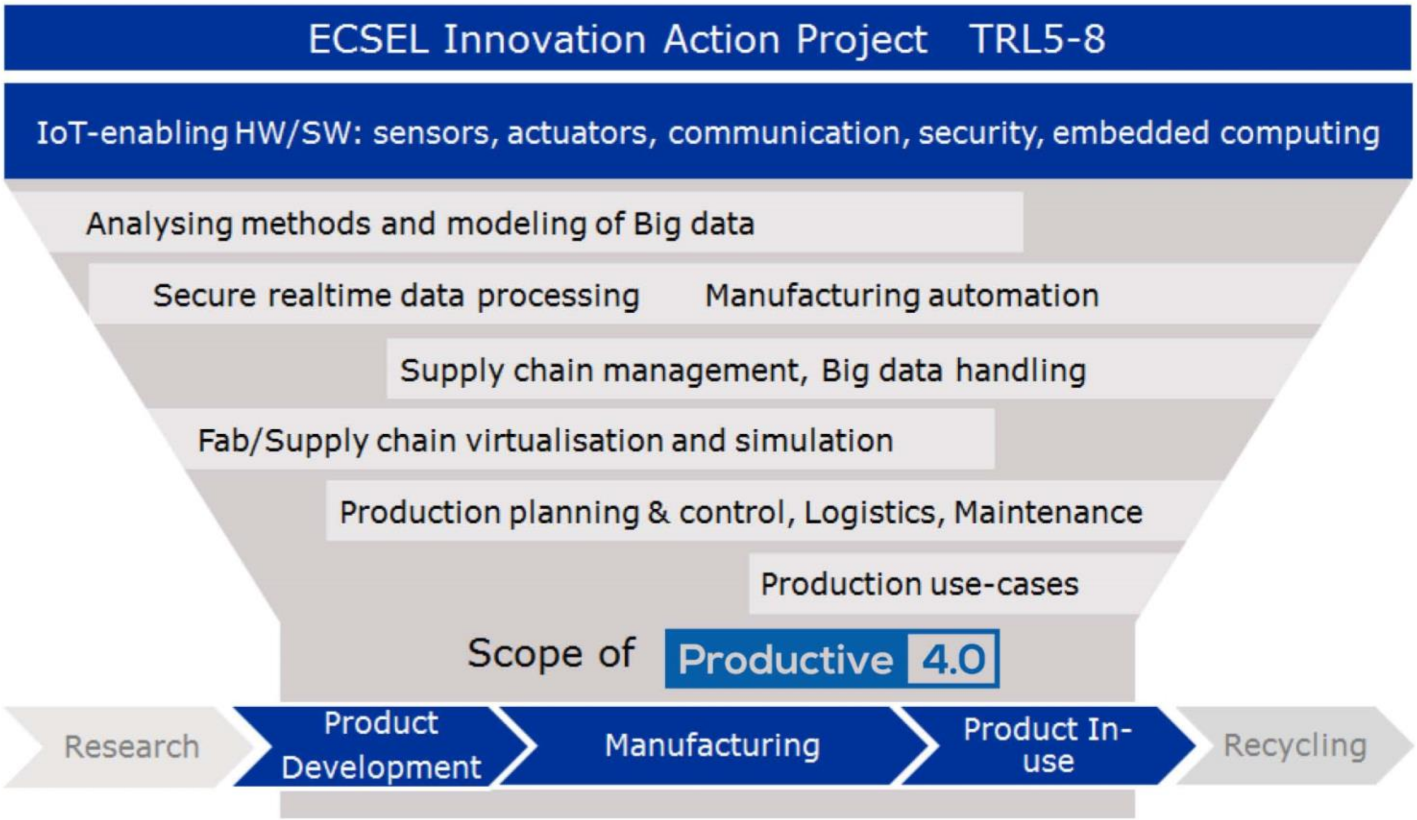


ECSEL Innovation Action & Lighthouse

Productive 4.0 — Electronics and ICT as enabler for digital industry and optimized supply chain management covering the entire product lifecycle

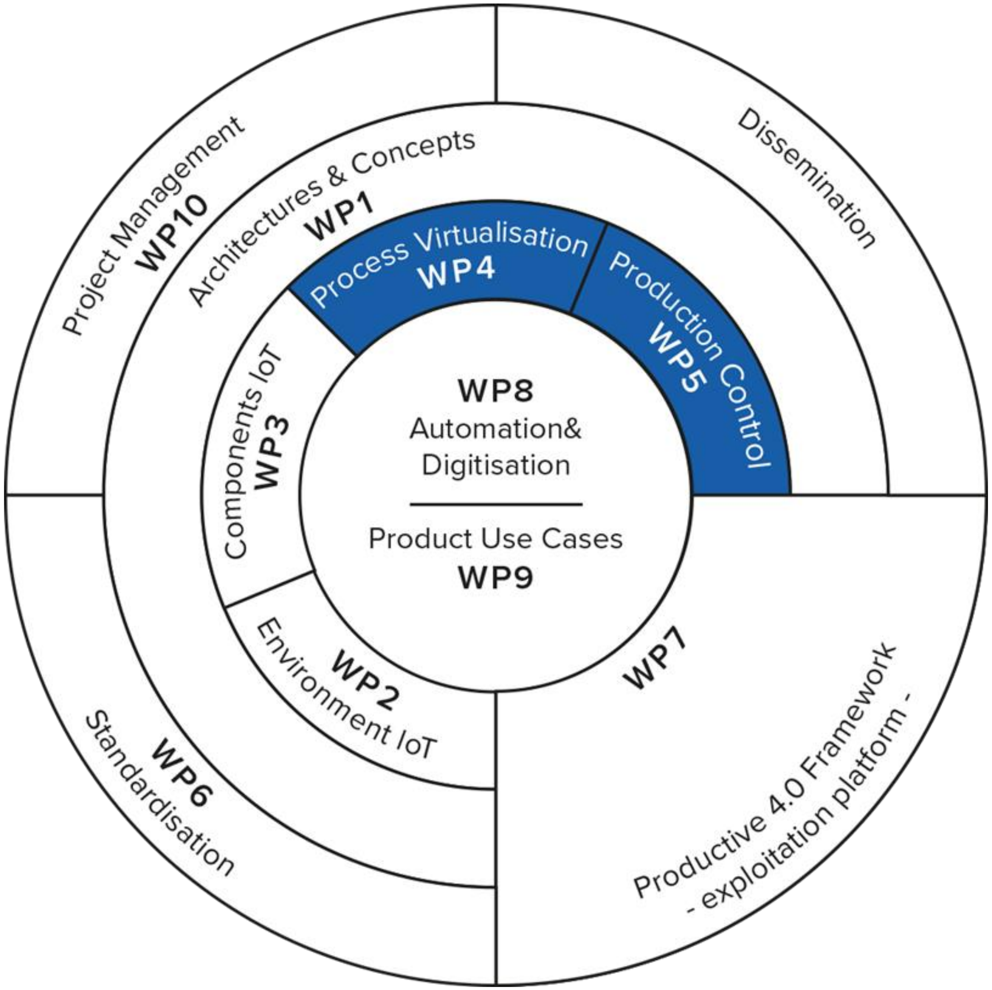
The Research Project *Productive4.0*

- Scope of the project



The Research Project *Productive*4.0

- Project Structure
  - Work Package 4
    Develop a virtual simulation framework for modelling complex manufacturing systems and supply chains
  - Work Package 5
    Develop Methods for Design Planning and Control of manufacturing systems and the supply network



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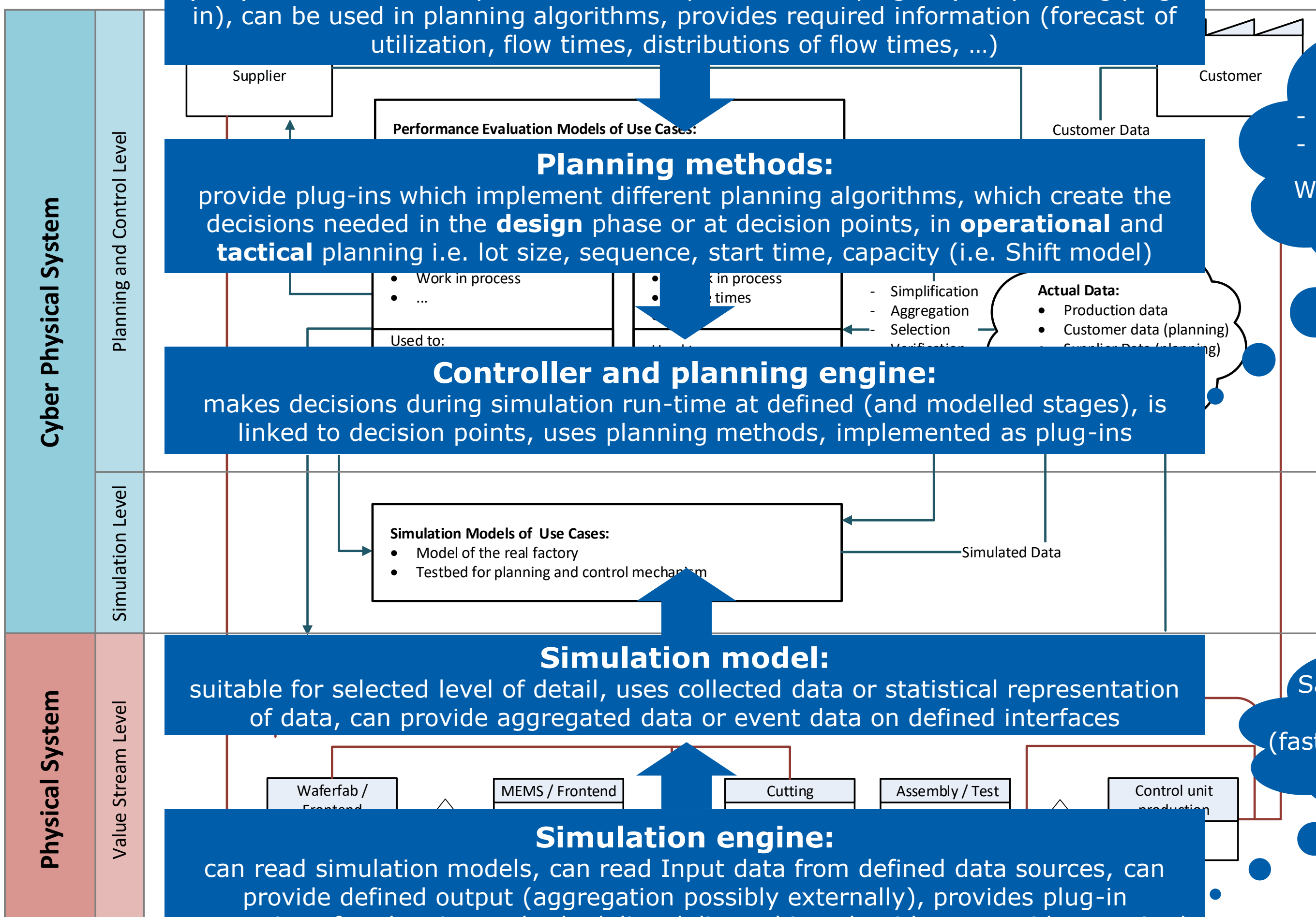
The Methods and Tools of WP4 & WP5 of *Productive4.0*



Performance Evaluation Tools:
(fast) simulation or analytical methods implemented as plug-in (in a planning plug-in), can be used in planning algorithms, provides required information (forecast of utilization, flow times, distributions of flow times, …)

Planning methods:
provide plug-ins which implement different planning algorithms, which create the decisions needed in the **design** phase or at decision points, in **operational** and **tactical** planning i.e. lot size, sequence, start time, capacity (i.e. Shift model)

Controller and planning engine:
makes decisions during simulation run-time at defined (and modelled stages), is linked to decision points, uses planning methods, implemented as plug-ins

Simulation model:
suitable for selected level of detail, uses collected data or statistical representation of data, can provide aggregated data or event data on defined interfaces

Simulation engine:
can read simulation models, can read Input data from defined data sources, can provide defined output (aggregation possibly externally), provides plug-in connections for planning and scheduling / dispatching algorithms, provides required data for these algorithm from current state, forecasts and statistical sources

Data access for planning and controller methods
- Through simulation engine (likely)
- Directly

What about historic data, statistics, future data (forecasts)

Same or different simulation engines for performance evaluation (fast simulation) used in decision making and in testbench or different ones?

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Literature Review - Characteristics of modelling a large scale manufacturing networks

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Reference	Target	Model		Considered Characteristics								Result
		Type	Time	Reentrance	Blocking	Arrival Process	Service Process	Multi-Server	Service Disciplines	Batches	Downtimes	
Morrison and Martin (2007) Kim and Morrison (2011)	D	Queuing station	AC			G	G	x	FCFS		x	Cycle Time
Ding et. al (2007)	D	Markov chain model	AC			M	M	x	GEO	x	x	Cycle Time
Akhavan-Tabaaetabi et al. (2012)	D	State-dependent Markov chain model	AC			G	G	x	FCFS		x	Work-in-Process Cycle Time
Grosbard et al. (2013)	D	Open queuing network	AC	x		G	G	x	FCFS	x	x	Cycle Time Waiting Time
Sagron et al. (2015)	D	Open queuing network	AC			G	G		FCFS TP		x	Waiting Time
Scholl and Domaschke (2000)	D	Discrete event simulation	S	x	x	G	G	x	ESD		x	Cycle Time
Sivakumar and Chong (2001)	D	Discrete event simulation	S	x	x	G	G	x	ESD		x	Cycle Time
Pearn et al. (2009)	D	Fitted Gamma distribution	AC			-	-		-			Waiting Time Cycle Time
Tai et al. (2012)	D	Fitted Weibull distribution	AC			-	-		-			Waiting Time Cycle Time
Akhavan-Tabatabaei et al. (2009)	D	Flow Analysis Model	AC			-	-		-		x	Work-in-Process Cycle Time

Target: D – Design Time: AC - Analytical Continuous, S - Simulation

Productive 4.0 ECSEL JU

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		Type	Time	Reentrance	Blocking	Arrival Process	Service Process	Multi-Server	Service Disciplines	Batches	Downtimes	
Veeger et al. (2010a, 2010b)	D	EPT-based aggregate simulation model	AC			G	G	x	FCFS		x	Cycle Time
Veeger et al. (2011)	D	EPT-based aggregate simulation model	S			G	G		FCFS LCFS		x	Cycle Time
Can and Heavey (2017)	D	EPT-based discrete event simulation	S		x	M	M	x	FCFS		x	Cycle Time
Yang et al. (2011)	D	Simulation-based metamodeling	S			-	-	x	TP			Cycle Time
Yang (2010)	D	Neural network metamodeling	S			-	-	x	TP			Cycle Time
Hsieh et al. (2014)	D	Progressive simulation metamodeling	S			-	-		TP	x		Cycle Time
Schelasin (2011, 2013)	D	Static capacity model Queueing station	AC			G	G	x	FCFS		x	Waiting Time Cycle Time
Zisgen and Meents (2008) Brown et al. (2010)	D	Open queuing network	AC	x		G	G	x	FCFS	x	x	Cycle Time Queue Lengths
Zarifoglu et al (2013)	O	Queueing Model	AC			G	G		FCFS	x		Optimal Lot Size
Chang (2017)	O	Simulation	AC	x		G	G	x	TP	x		Optimal Product Mix

Target: D – Design, O - Optimisation   Time: AC - Analytical Continuous, S - Simulation

Literature Review - Characteristics of modelling a large scale manufacturing networks

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		Type	Time	Reentrance	Blocking	Arrival Process	Service Process	Multi-Server	Service Disciplines	Batches	Downtimes	
Wang and Wang (2007)	O	Simulation	S	x		G	D	x	FCFS	x		Optimal Lot Size
Akhavan-Tabatabaei et al. (2011)	O	Simulation	S	x		M	M		FCFS		x	Optimal Lot Release
Fowler et al. (2002)	O	Queueing Station	AC			G	G	x	FCFS	x		Optimal Batch Size
Kuo et al. (2011)	O	Neural Network	AC			G	G	x	FCFS	x	x	Reduce Cycle Time
Li et al. (2010)	O	Queueing Network	AC		x	M	M		FCFS		x	Optimal WIP level
Wang et al. (2013)	O	Neural Network	AC			G	G		OPT			Optimize Service Discipline
Chien et al. (2012)	O	Neural Network	AC			-	-		-			Reduce Cycle Time
Yao et al. (2004)	O	Modelling Framework	AC			-	-		-		x	Maintenance Scheduling
Ramirez-Hernandez et al. (2010)	O	Simulation	AC			-	-		-		x	Maintenance Scheduling
Kalir(2013)	O	Queueing Station	AC			G	G	x	FCFS		x	Optimize FM Splitting

Target: O - Optimisation   Time: AC - Analytical Continuous, S - Simulation

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Conclusion and future research

- Usage of simulation and analytical models for the purpose of performance evaluation and especially cycle time estimation has been documented several times.
- Focus was usually set on an average cycle time, not on a percentile of the cycle time distribution.
- Dispatching and sequencing rules have also been studied, however, the impact on guaranteed performance figures is still open.
- Neural networks seem to be useful, when some data points for the system are available and the gaps between these data points have to be filled.
- Hybrid methods make use of the higher computing power available today, using combined knowledge from several sources.

Integration of data collection, planning algorithms and performance prediction of guaranteed cycle times with a high probability is an open task.

WP4 & 5 Process Virtualisation + Production Control
1. Overview

Partners

- INFINEON TECHNOLOGIES AG
- Robert Bosch Gesellschaft mit beschränkter Haftung
- SAP SE
- SIMPLAN AG
- FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V.
- FORTISS GMBH
- KARLSRUHER INSTITUT FUER TECHNOLOGIE
- UNIVERSITAET MANNHEIM
- UNIVERSITAET ZU KOELN
- AVL LIST GMBH
- INFINEON TECHNOLOGIES AUSTRIA AG
- UNIVERSITAET KLAGENFURT
- COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES
- ECOLE NATIONALE SUPERIEURE DES MINES DE SAINT-ETIENNE
- STMICROELECTRONICS CROLLES 2 SAS
- APPLIED MATERIALS BELGIUM
- DANOBAT
- Savvy Data Systems S.L.
- ENGINE POWER COMPONENTS GROUP EUROPE SL
- TRIMEK SA
- ULMA EMBEDDED SOLUTIONS S COOP
- IDEKO S COOP
- ASOCIACION DE EMPRESAS TECNOLOGICAS INNOVALIA
- MONDRAGON SISTEMAS DE INFORMACION
- MONDRAGON ASSEMBLY S.COOP
- PANEPISTIMIO THESSALIAS
- CENTRO DI PROGETTAZIONE, DESIGN & TECNOLOGIE DEI MATERIALI
- LFOUNDRY SRL
- POLITECNICO DI MILANO
- Statwolf Ltd.
- UNIVERSITY OF LIMERICK
- Infineon Technologies Ireland Ltd
- Infineon Technologies Cegléd Kft.
- UNGER FABRIKKER AS
- PREDIKTOR AS
- TELLU AS
- HOGSKOLEN I OSTFOLD
- STIFTELSEN SINTEF
- KOC UNIVERSITY

→ WP4: 26 partners, 611 person months

→ WP5: 39 partners, 1.256 person months

Next steps

- Productive 4.0 is an „innovation action“,
  if we do want to do more research we need:
  - Either a „Research and Innovation Action“ and/or a
  - Marie Skłodowska-Curie Action (or something similar)

- Find a way to include researchers from other continents (Amercia, Asia,….)

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Thank you for your attention!

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