Lean Digital Factory

Closed Loop Manufacturing Approach

Dr. G. Beitinger | November 2021

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What have we reached so far …?

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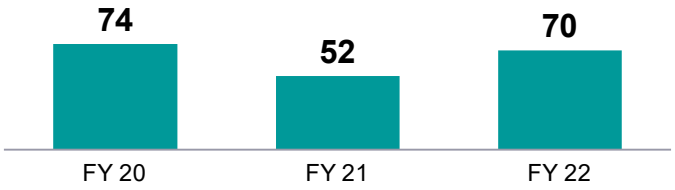
The innovation power of LDF is honored by winning several industrial awards, supporting to position Siemens as digital thought leader in the market

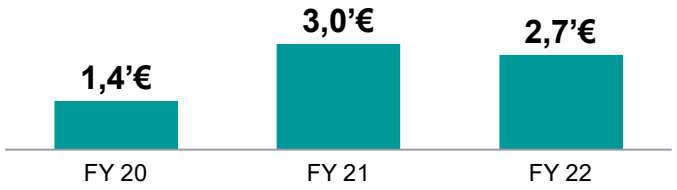
The development and scale-up of 4IR solutions is jointly driven according to aligned roadmaps.

Number of joint projects[1]



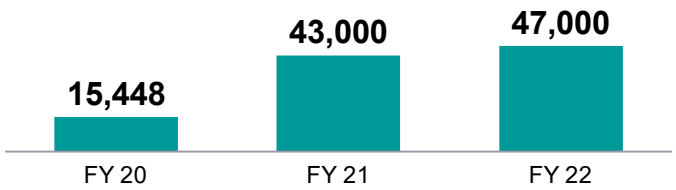
Up- & re-skilling program derived from LDF roadmaps, enabling DI employees to face digital change.

Expenses[2]



Learning channel on "My Learning World", fostering life-long learning and increasing the digital mindset of Siemens employees.

My LeWo views



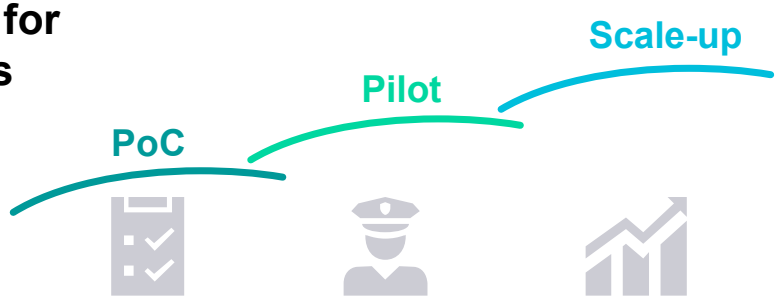
McKinsey & Comp

LDF is entering new territories …! [3]

1 PoCs, Pilots, Scale-ups; FY22 is forecast. | **2** Supported by "Future Fond" for 6.000 German DI employees. | **3** Statement during GWE visit with focus on automation of inbound logistics |
3 Statement during GWE visit with focus on automation of inbound logistics

LDF proves benefits of own products to customers and collaborates with R&D to take them to the next level

The LDF plants are a driver for the Siemens portfolio



- Based on aligned target states & reference processes, gaps of existing portfolio are identified
- New feature development for DI products supported by PoCs

- Internal solution providers learn from experiences made by LDF network to enhance own solution
- LDF plants are showcasing portfolio to external customers

Examples for collaborative development of new features, interoperability and consistency of existing portfolio

- MindSphere
- Opcenter advanced (e.g. CAMSTAR, Valor PP)
- Modular MES
- Teamcenter manufacturing, Easy Plan
- ARTIMINDS
- Plant Simulate-Teamcenter Integration
- Process Simulate-Teamcenter-NX Integration
- IEC-NX-Line Designer-Toolbox
- Industrial Edge
- SIMOVE
- Solution Link
- …

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Excellence in manufacturing
For our customers

Our Mission

"Be the Role Model for Excellence in Production and Logistics to provide proven Value Add for our Customers and Business Units, based on the methods of Digital Enterprise and Lean Industrial Engineering

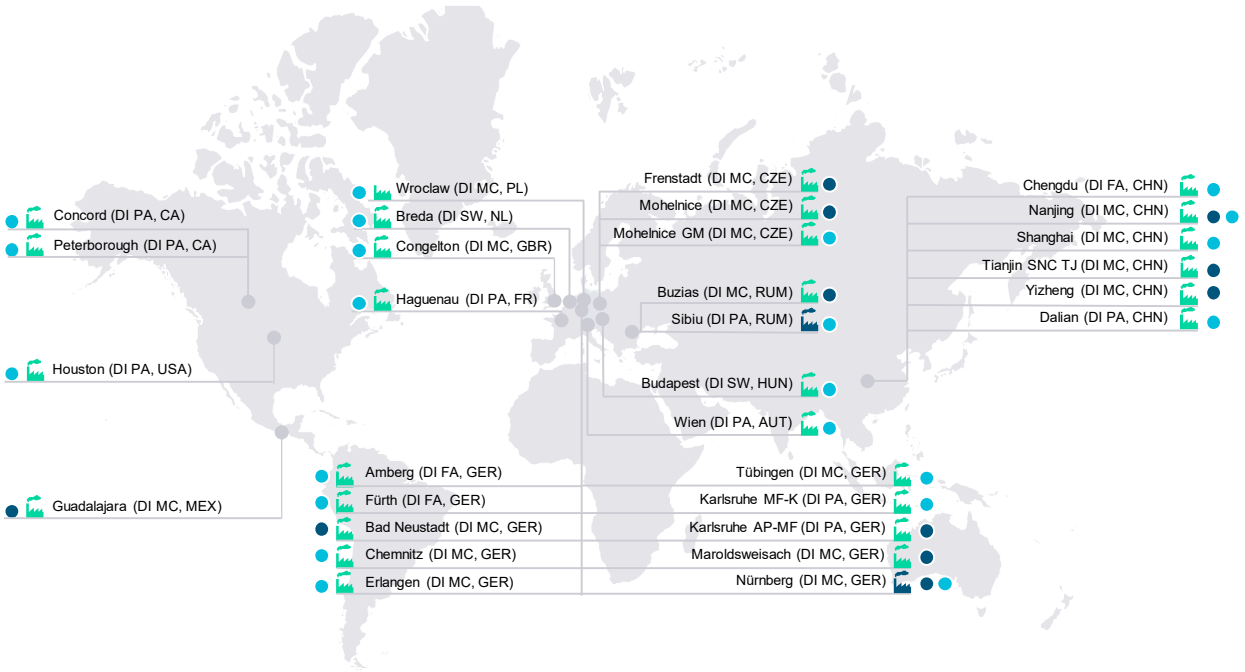
Shape the Digital Future. Together."

Dr. Gunter Beitinger, SVP Manufacturing; Head of Factory Digitalization & Product Carbon Footprint

Our Framework

- Evaluate new Business models
- Shorten time to market
- Increase flexibility
- Improve quality
- Boost efficiency
- Increase security
- Sustainability

Our Footprint



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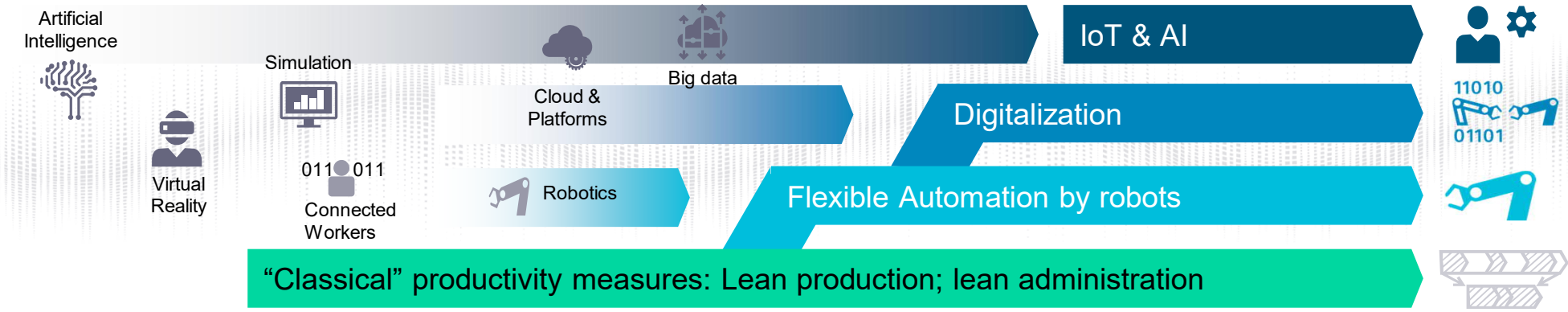
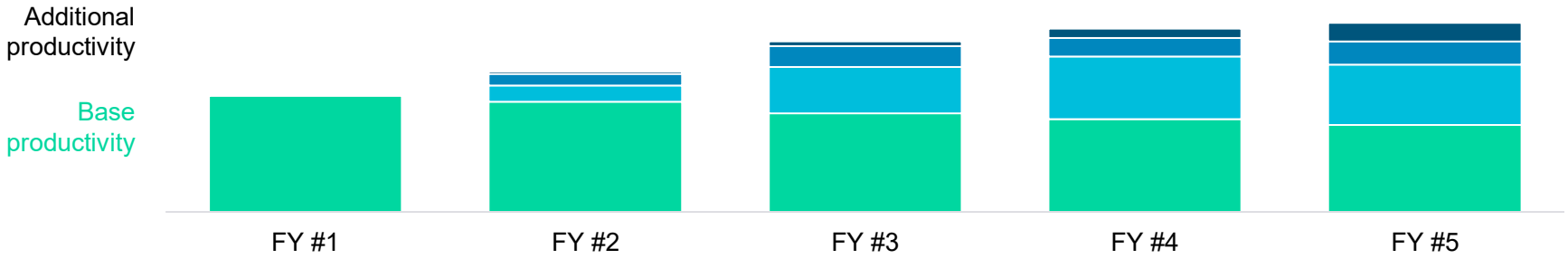
Siemens DI factories strengthen the focus on automation and digitalization hand in hand with lean productivity





>50%
by automation, digitalization and IoT & AI

<50%
by Lean

Long-term

LDF guides the way to Digital Transformation

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Lean Digital Factory

Digitalization Approach for over 30 plants

Ideation

Organizational setup

Technology workshops

Reference processes

Reference process design

Technology radar

Mapping software platforms

Digitalization roadmaps

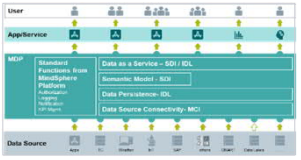
- Digital Twin
- Processes
- Big Data & Analytics
- Autonomous Manufacturing Systems
- New Ways of Working

Reference IT architecture

IT Roadmap/Functions

SolutionLink Analysis

MDP Architecture



Realization phase

POC

- Concept evaluation in best-fit factory
- Savings potential verification
- Definition of scalable solution for all factories in the network
- Start of ~40 PoCs in July 18

Pilot

Implementation of dedicated standard concept within a specific environment to leverage first savings

Scale-up

Parallel implementation of dedicated concept across all business units and their environments

Continuous roadmap update

Technology Scouting

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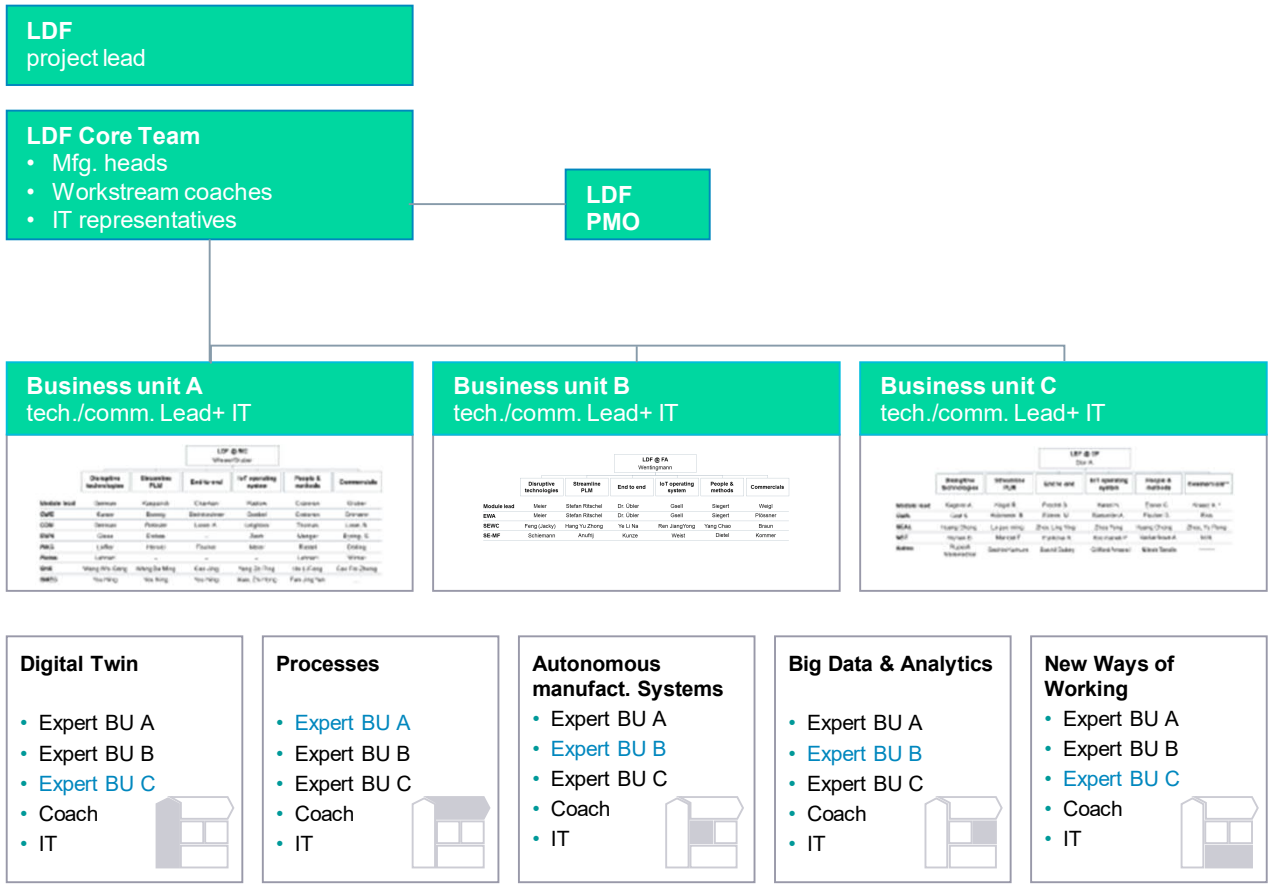
LDF drives standardization and cross business unit collaboration among the entire factory landscape

Lean Digital Factory (LDF) set-up

- Project lead guides experts with support and buy-in from core team
- Strong PMO is crucial to coordinate, structure and enable project organization
- Key experts from each business unit are forming one team per workstream
- Workstream structure is mirrored in all plants to accelerate knowledge exchange and collaboration on all levels

> “In addition to the financial and processual potentials, cross-BU collaboration within LDF formed a solid network – enabling sharing of ideas and innovation even beyond the project scope”



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Meeting cascade established facilitating regular exchange across BUs and LDF levels

Meeting cascade

The established cascade facilitates bi-directional communication throughout DI

	Month 1				Month 2			
Touch Points	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**	**Week 7**	**Week 8**
Core Team	▬		▬		▬		▬	
BU Leads & PMO	▬	▬	▬	▬	▬	▬	▬	▬
BU specific LDF alignments: LDF@FA, LDF@GME, LDF@GMM, LDF@PA		▬		▬		▬		▬
Workstream Digital Twin	▬		▬		▬		▬	
Workstream Process		▬		▬		▬		▬
Workstream Big Data & Analytics	▬		▬		▬		▬	
Workstream Autonomous Manufacturing Systems		▬		▬		▬		
Workstream New WoW	▬		▬		▬		▬	
PoC & Pilot Teams	▬	▬	▬	▬	▬	▬	▬	▬

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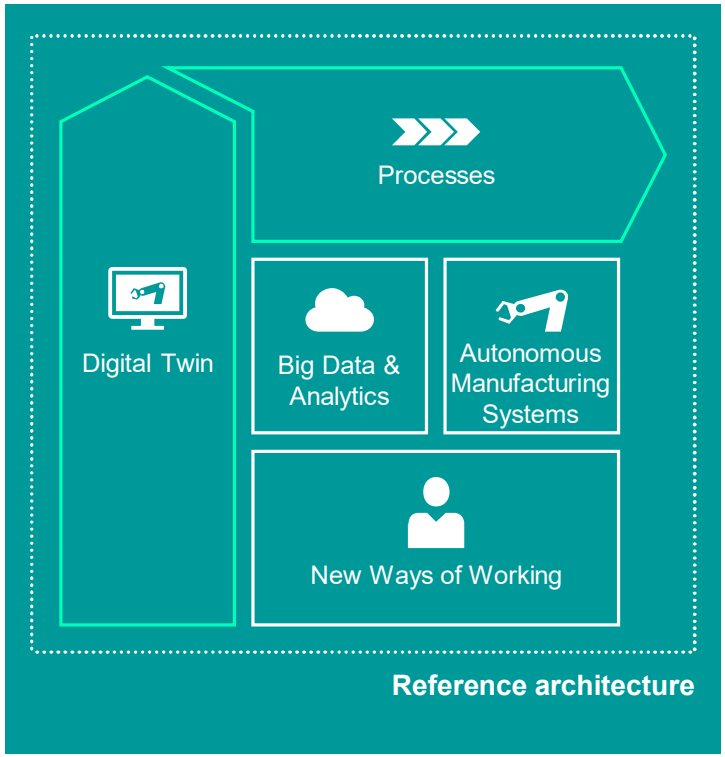
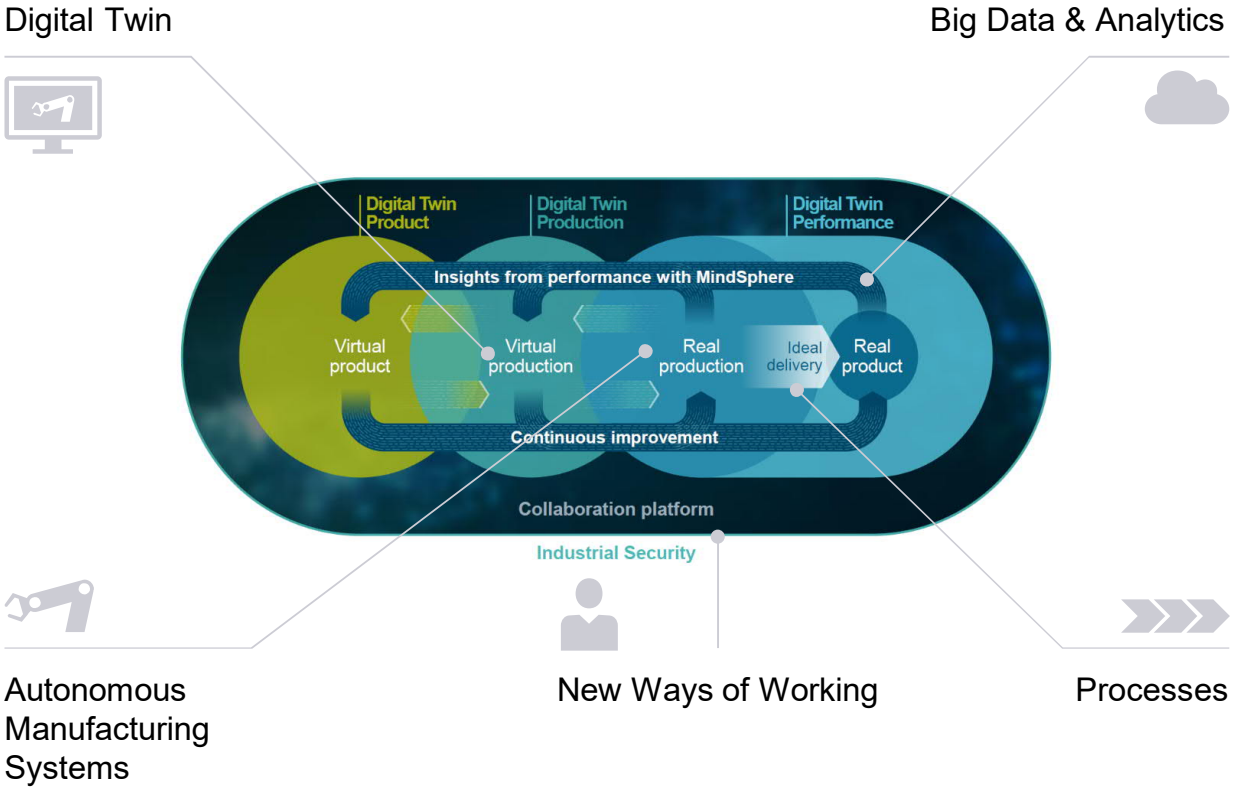
The five LDF workstreams serve the generally acknowledged Digital Factory vision

Lean Digital Factory (LDF) workstreams



Workstreams serve Digital Factory vision



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Roadmaps to ensure holistic view on Digitalization per function and support stringent implementation

Idea and approach for Digitalization Roadmap

Idea

Sub-projects **develop first draft of Digitalization Roadmap** to …

… **find new Digitalization measures** beyond classical ideas

… **understand interdependencies** between defined measures

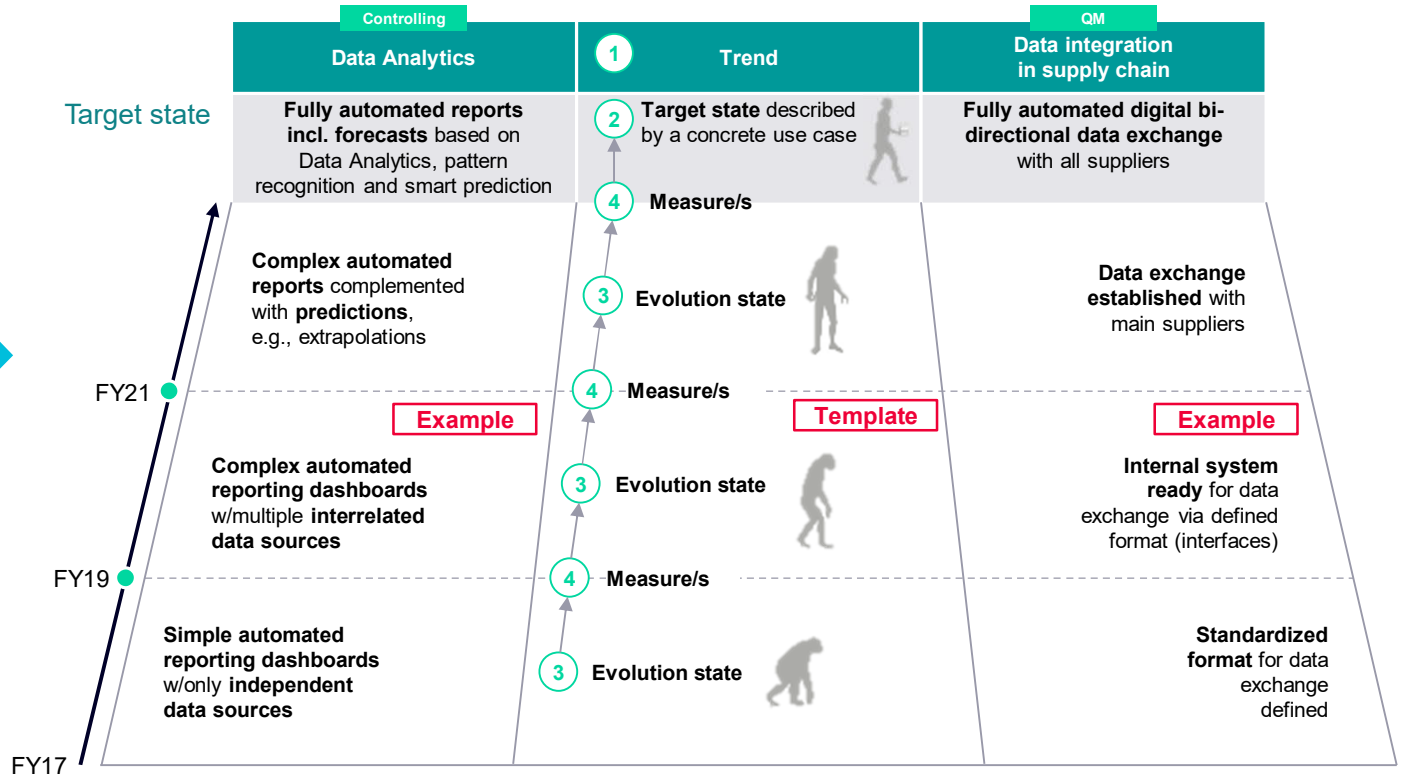
… **enable mgmt. to trace progress** of Digitalization

Approach

1. **Identify** relevant **Digitalization trends**
2. **Concretize trend** through target state for specific function
3. **Define evolution states** and detail way to target state
4. **Elaborate and prioritize measures** to realize target states

Example/template

Due to high dynamic of Digitalization the Roadmap is a working document



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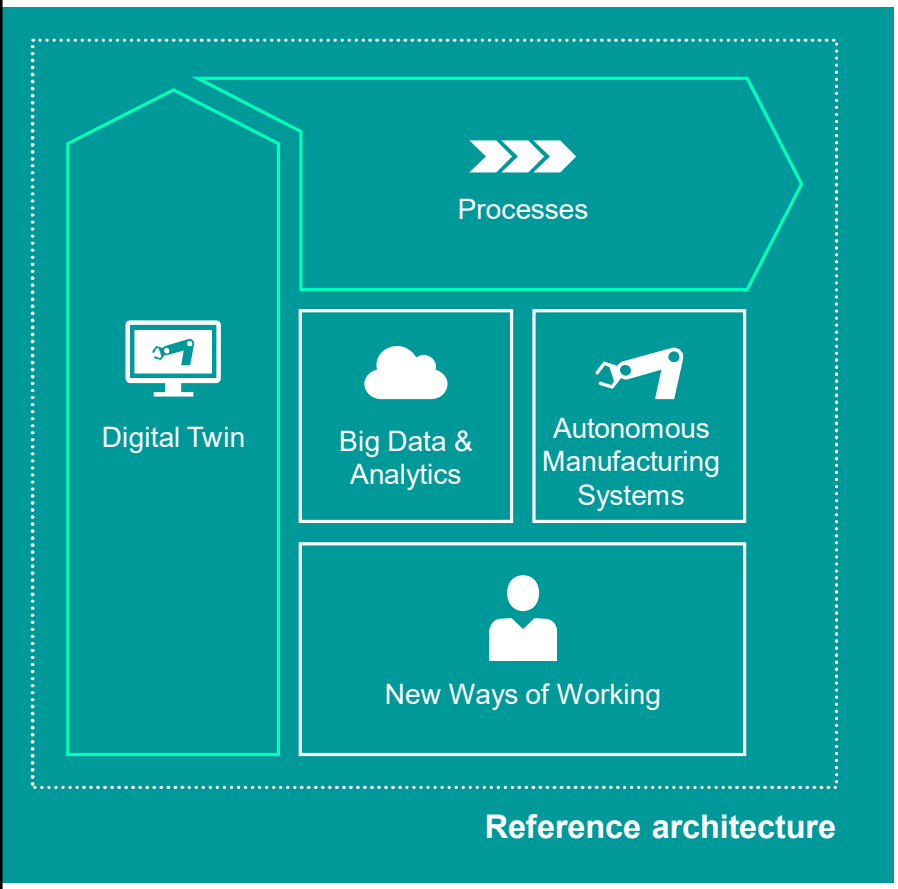
The workstreams “Digital Twin” and “Processes” are supported by defined enabler workstreams



Lean Digital Factory (LDF) workstreams

Digital Twin
Fast and reliable production introduction with simulation based on the digital twins of product and production

Processes
Synchronized planning of all production resources and activities in the supply chain for short lead times and maximum utilization

Big Data & Analytics
Availability of all relevant information about the supply chain in the cloud and creation of new insights with analytics and AI
Enabler

Autonomous Manufacturing Systems
Increased productivity through automation in production and logistics
Enabler

New Ways of Working
Create a digital mindset to foster new ways of efficient collaboration in a digital factory & enhance automation & digitalization understanding
Enabler

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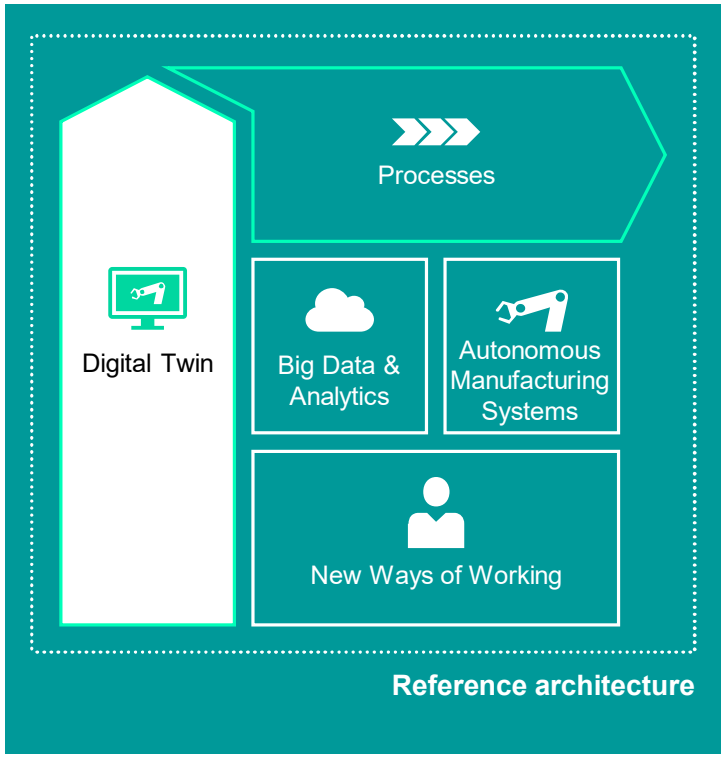
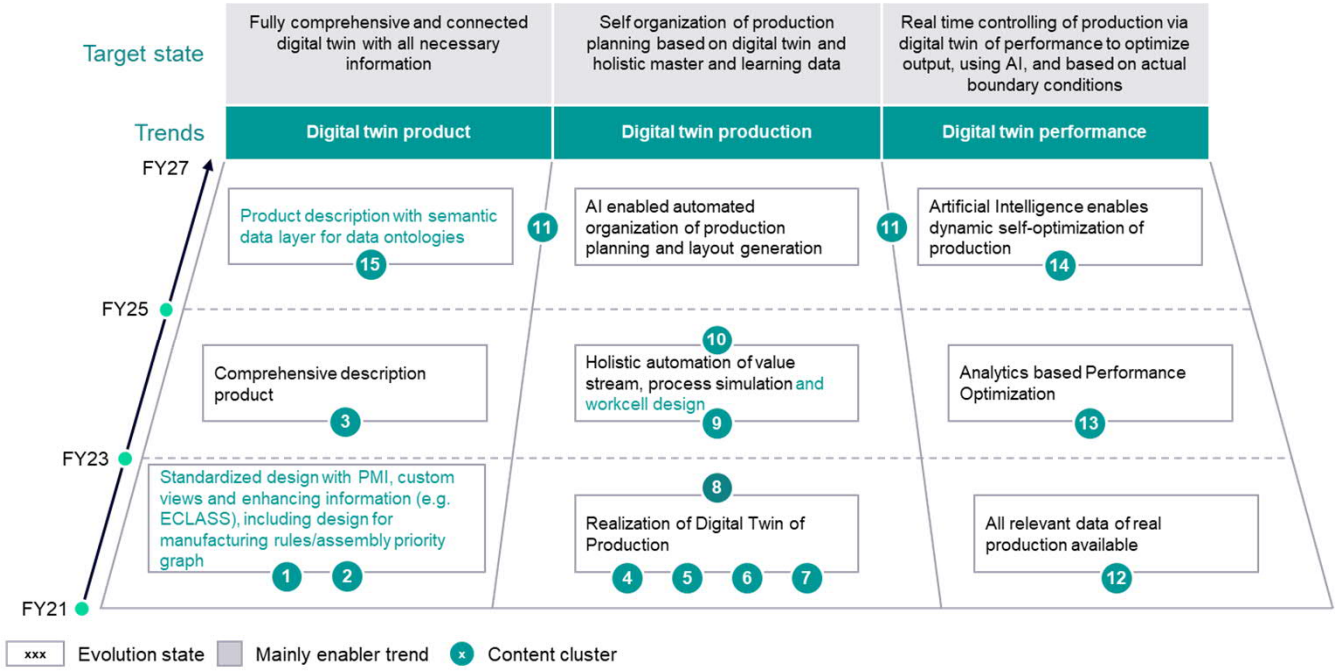
Automated production engineering increases speed and efficiency via holistic digital twins

Lean Digital Factory (LDF) workstreams





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Automated production engineering increases speed and efficiency via holistic digital twins

Digital – Digital Twin

Comprehensive automated production engineering & optimization based on consistent usage of holistic digital twin to increase engineering efficiency and speed-up time-to-market

- Production engineering is automated, enabled by full-featured Digital Twins of Product, Production & Performance. These digital twins are aligned to the eCl@ss cross-industry standard and contain all levels of detail to automize the process from product design to production on the shopfloor. The high degree of automation in the engineering process based on AI and supported by a knowledge database raises the efficiency and speeds up time-to-market to lay the foundation for shorter innovation cycles. This is supported by the automated programming of machines (in Mentor Valor PP or NX CAM). All tasks are coordinated by an overarching Mendix workflow system guiding through the whole process and ensuring fast execution. Seamless interoperability between all involved systems eliminates manual efforts for data preparation and raises output efficiency & quality of production engineering by providing comprehensive data
- Integrated simulation of the production process in the virtual factory increases the reliability of production engineering. This ensures that the engineered production system will deliver the targeted performance with zero defects in the first place. Therefore all tasks from work cell design to optimization in the context of the whole factory infrastructure including logistic, workforce and maintenance are digitally assisted with Process Simulate, Line Designer and Plant Simulation. Automatic human work design calculation is carried out (TiCon4Teamcenter), while generating new work plans for process optimization
- The digital twin of performance closes the loop to the real-world production by providing real-time data from the Manufacturing Data Ecosystem to initiate optimizations according to actual boundary conditions with AI

Speed
- Time-to-market
- Data consistency

Flexibility
- Easy product relocation
- Product configuration

Quality
- Integrated FMEA
- Integrated Control Plan
- DfM

Efficiency
- Output efficiency of production
- Engineering effort

Scalability

Sustainability

Applied SAG Portfolio
- Teamcenter
- Mendix
- MindSphere
- NX Line Designer
- Check-Mate
- Process Simulate
- Plant Simulation
- Mentor Valor PP
- NX CAM

Impact on category

EPEI: Every part every interval

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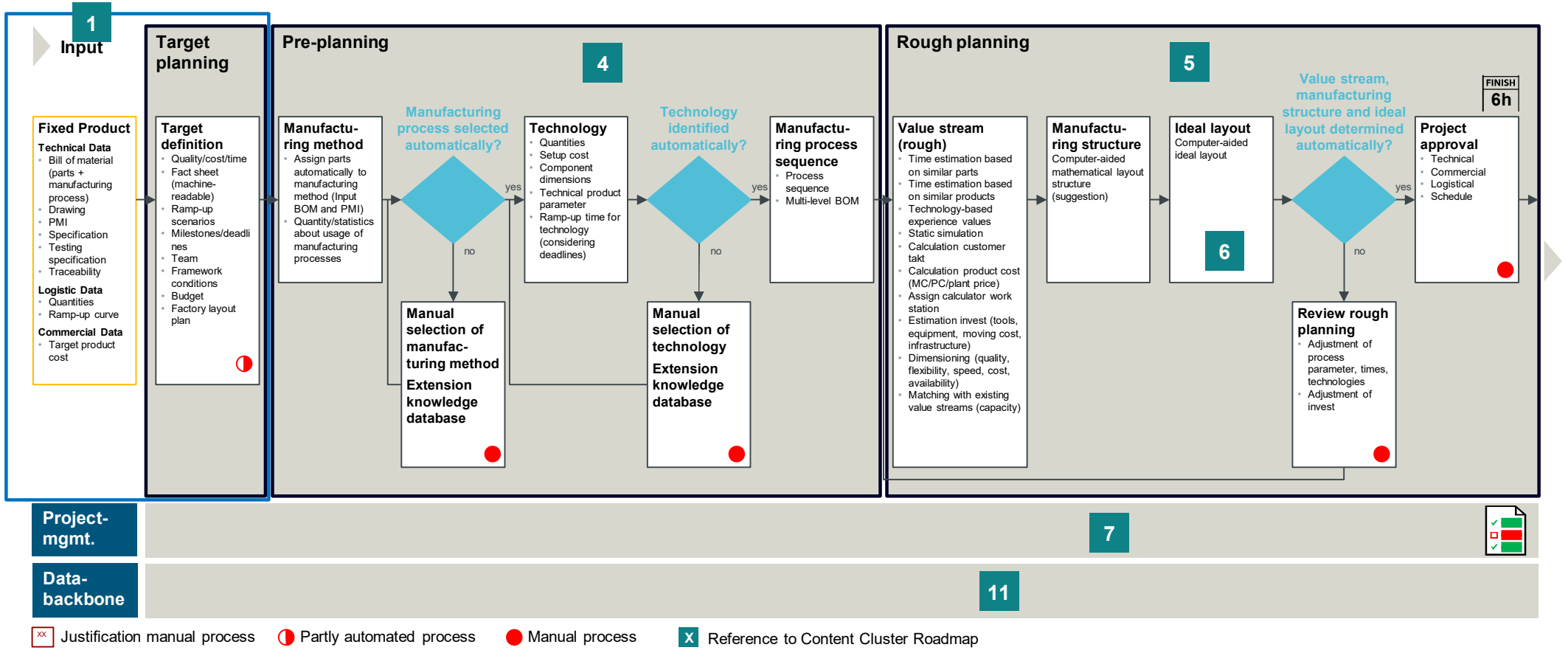
The reference process shows a concept for automation and acceleration of production system planning by digitalization

Reference process production system planning – Target planning to rough planning (Section 1/3)



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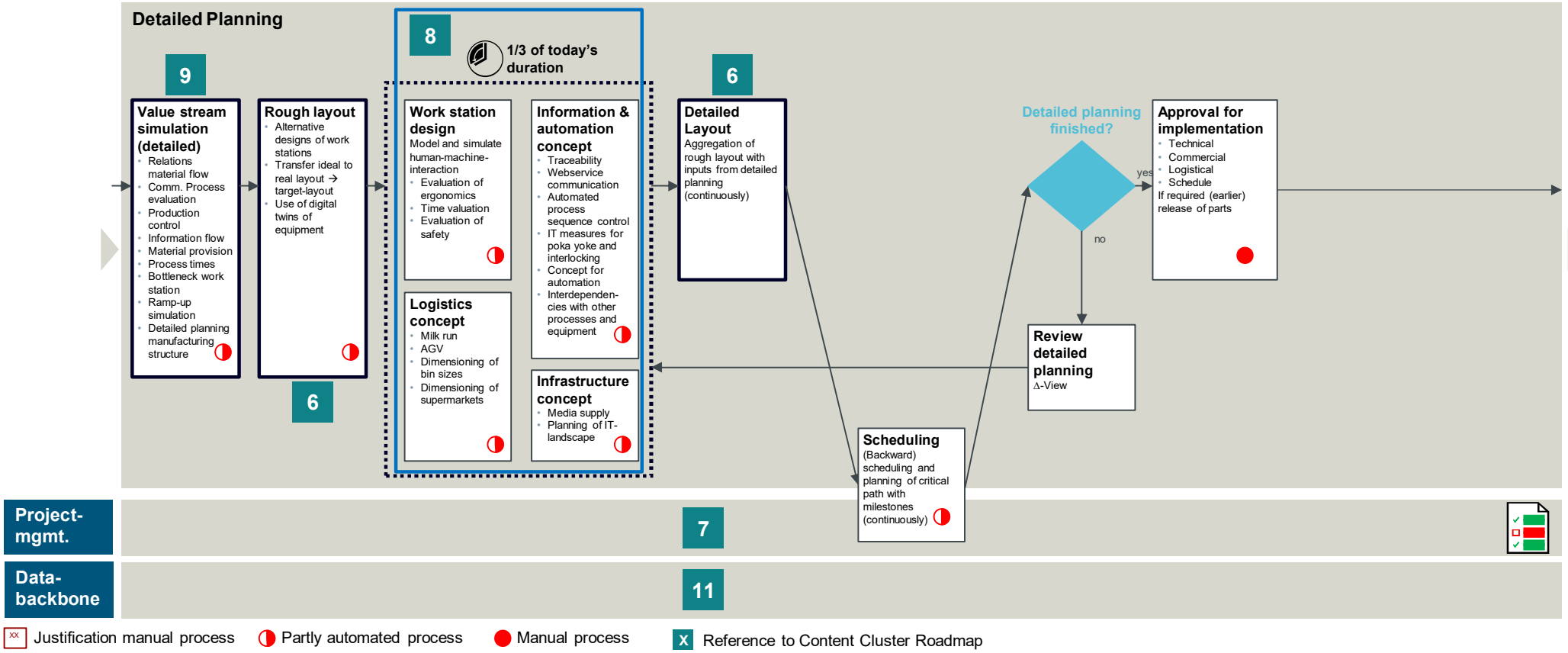
The reference process shows a concept for automation and acceleration of production system planning by digitalization

Reference process production system planning – Target planning to rough planning (Section 2/3)



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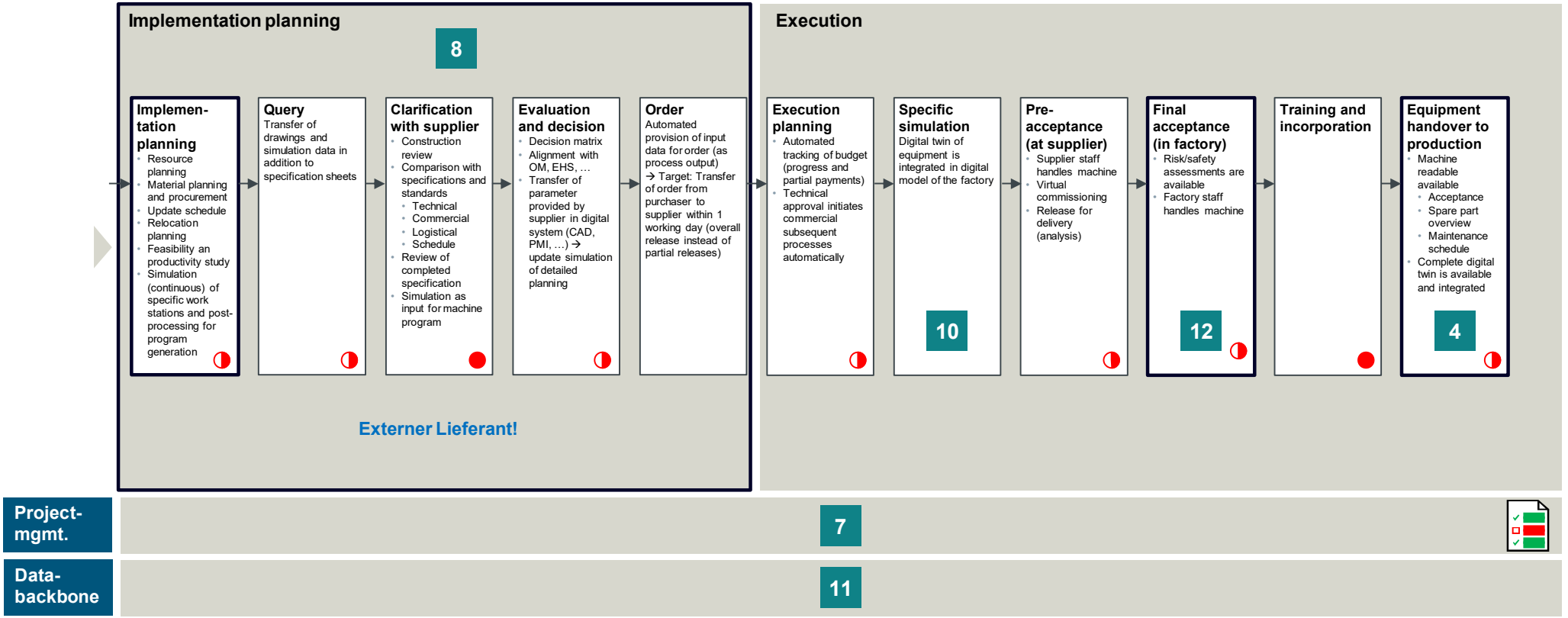
The reference process shows a concept for automation and acceleration of production system planning by digitalization

Reference process production system planning – Target planning to rough planning (Section 3/3)



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A common resource library for DI factories is being established as a basis for plant and process simulations

Trend: “Digital Twin”

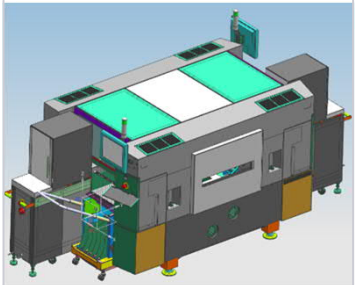
Setup a common library with standardized formats

- Simplification & standardization of CAD data from machine suppliers
- Derivation of reference models and assignment of attributes

Common basis for plant and process simulations

Feedback to Siemens Technical Machines Specification

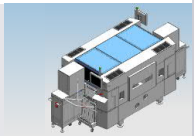
Native Data
(NX-Import)



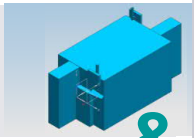
- Inconsistent between suppliers
- Poor performance due to e.g., duplicated objects
- No defined orientation

Case specific reference models
(e.g. Resource “Siplace XYZ”)

Modell
3D-planning and kinematics simulation



Simple
High-performance 3D-Planing of large areas



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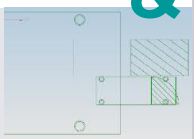
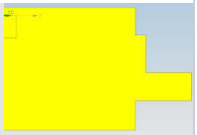
2D-Layout
Layout planning of whole plants



Build area:
Simplified evaluation of space requirements



Teamcenter Attributes

- Classifications, e.g., SMT machine
- Connections: Electrical, compressed air, etc.
- Invest: Vendor, normal/special costs
- Plant Sim attributes: Class, MTTR, availability

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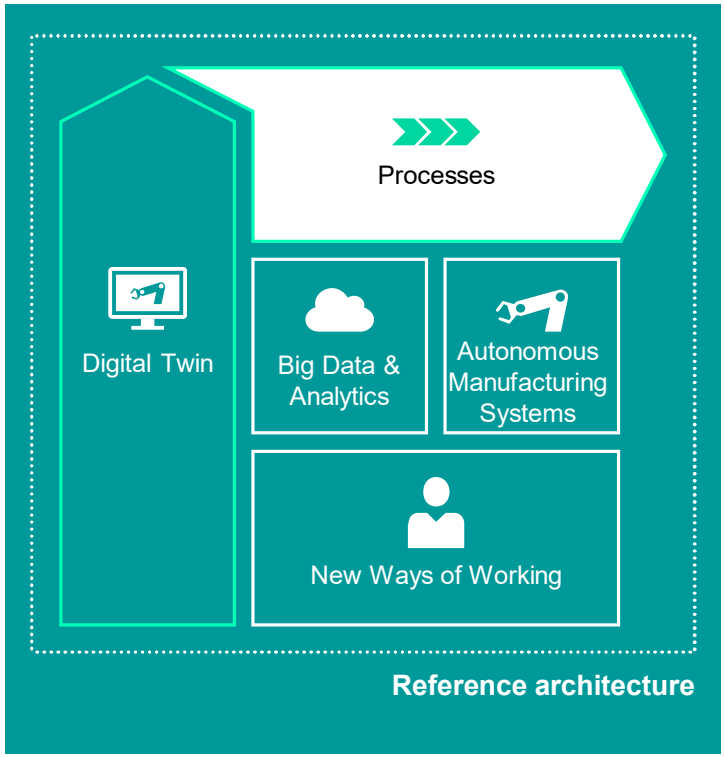
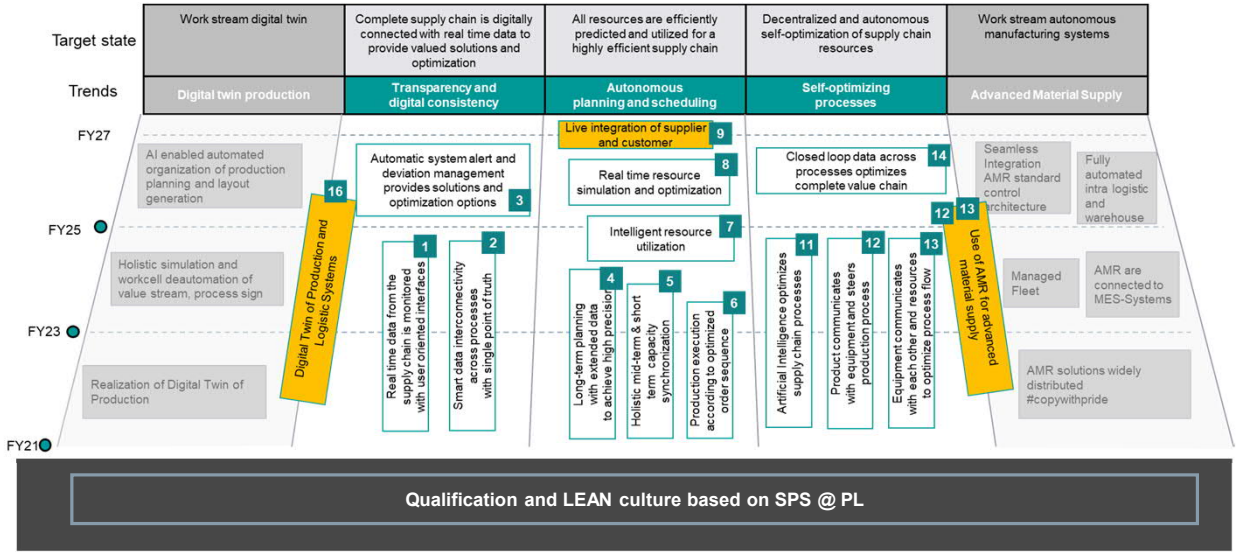
LDF Processes (E2E) - Autonomous coordination of supply chain resources based on artificial intelligence and real time transparency to maximize speed and efficiency

Lean Digital Factory (LDF) workstreams





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Cyber-physical systems for an autonomous coordination of the processes in the supply chain to improve efficiency and speed

Digital – Processes

Autonomous E2E-coordination of supply chain resources based on artificial intelligence and real time transparency to maximize speed and efficiency

- All resources (material, machines, workers, tools and fixtures) along the end-to-end supply chain are simultaneously considered in both capacity utilization and prediction (short & long-term) to maximize production efficiency of machinery and workers, using Opcenter APS
- Products and production have the ability to directly communicate with each other for decentralized, autonomous self-optimization of production execution under consideration of actual boundary conditions to reduce manual effort for production planning and control on shopfloor level. Therefore an agent-based architecture of cyber-physical production systems is the blueprint to raise the flexibility of our Manufacturing Execution Systems to the next level with adaptable microservices
- Real-time data from the supply chain are monitored continuously to detect deviations at the earliest point in time to increase the options for action. Therefore external data from the Supply Chain Suite & AX4 are considered simultaneously with internal material and resource position information from the Real-Time Location System (SIMATIC RTLS) with the accuracy of just centimeters. Based on this transparency the system automatically provides valued solutions in case of deviations with a self-learning system to increase the efficiency in deviation management

Speed
- Lead time

Flexibility
- Setup time
- Lot size

Quality
- OTD

Efficiency
- Productivity in planning and operations
- Utilization of recourses
- Stock & WIP reduction

Scalability

Sustainability

Applied SAG Portfolio
- Opcenter APS
- Opcenter family
- MindSphere
- SIMATIC RTLS
- Supply Chain Suite
- AX4

Impact on category

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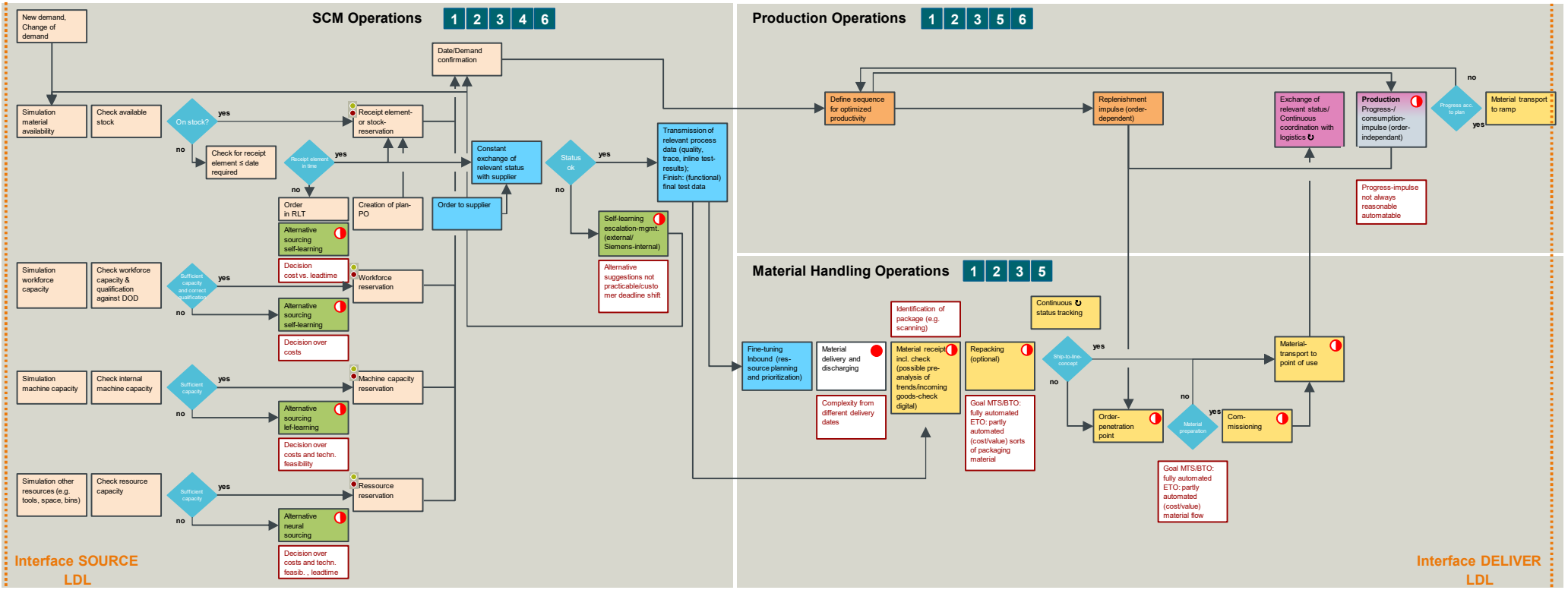
Cyber-physical systems for an autonomous coordination of the processes in the supply chain to improve efficiency and speed

Reference process Inbound- and Intralogistics



Synchronizing point for resource reservation | XX Justification manual process | Partly automated process | Manual process | 5 Reference to LDF Processes – Content Cluster

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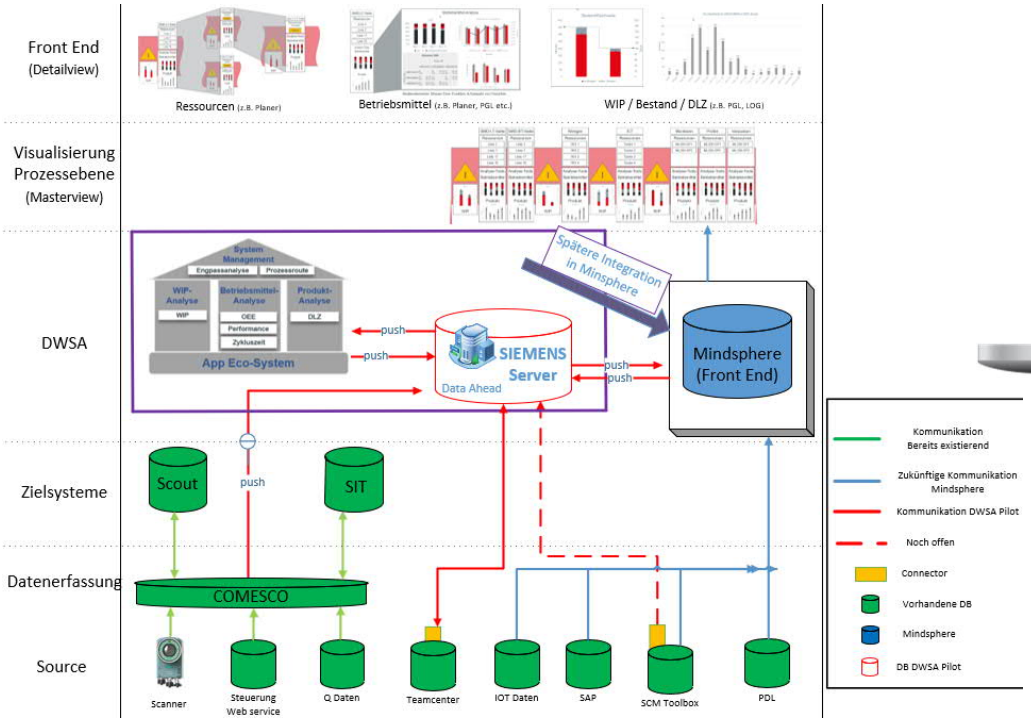
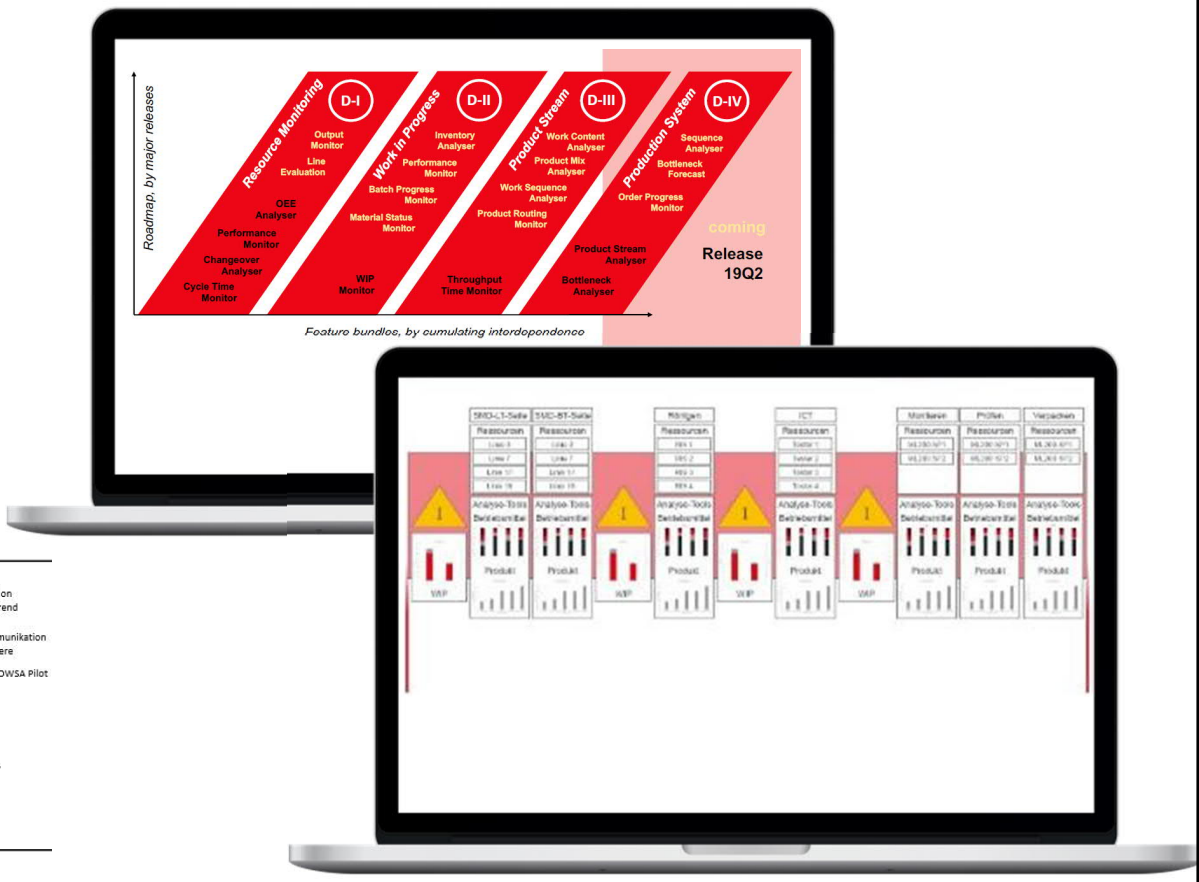
Digital value stream analysis (DVSA)
A real Lean Digital tool for factories





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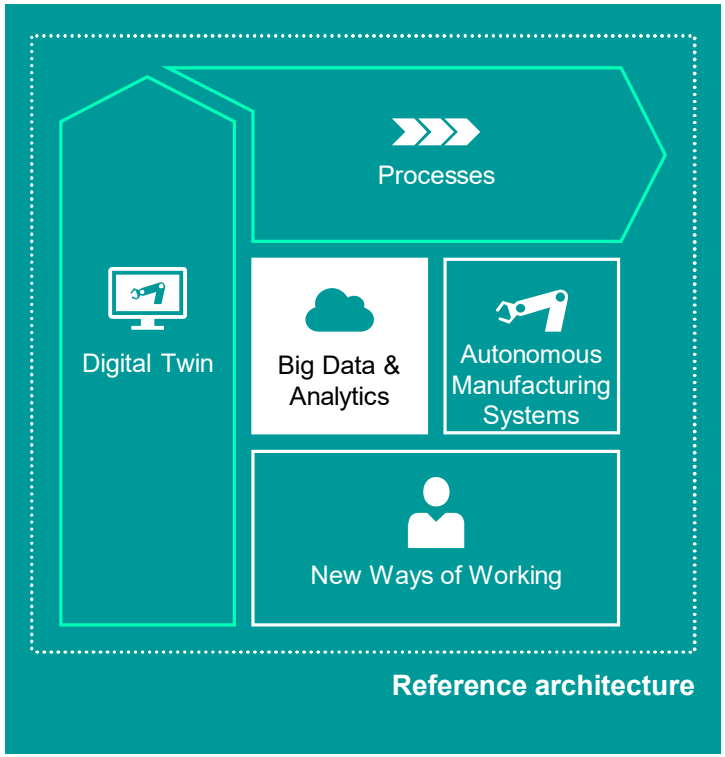
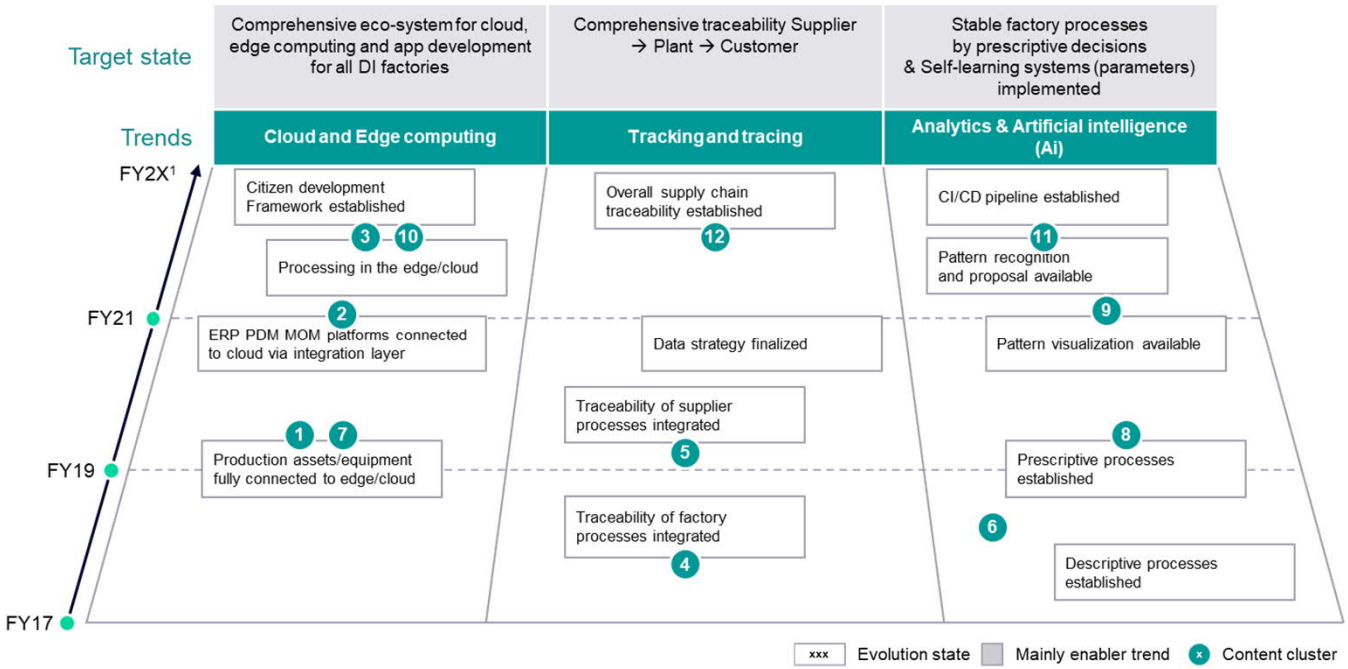
Manufacturing Data Ecosystem increasing quality, efficiency and scalability

Lean Digital Factory (LDF) workstreams





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Manufacturing Data Ecosystem increasing quality, efficiency and scalability

Digital – Big Data & Analytics

A comprehensive Manufacturing Data Ecosystem, using artificial intelligence to increase quality and efficiency in production while laying the foundation for scalability

- As a complete Manufacturing Data Ecosystem (MDE) is in place we can get additional insights into machines behavior and processes and therefore can turn data into value. The MDE consists out of an “Industrial Edge” platform, a state-of-the-art manufacturing data platform concept by MindSphere (MDP) and data source connectivity to feed data into a raw data store and an open analytic platform
- The ecosystem enables data citizens and analysts to dashboard information or to get deep process insights to improve, predict or stabilize manufacturing processes, in an efficient way without manual data preparation. For this data and algorithms can be stored, provided, transformed and AI models are trained on cloud and/or edge environment, enabling closed loop manufacturing, machine learning and comprehensive cross-factory reporting and decision-making without compromising IT security
- A total and comprehensive traceability and tracking concept is enabled for quality, warranty, engineering and sustainability requirements, also due to the embedded data persistence in the Manufacturing Data Platform. All relevant information correlated in all dimensions is available to allow holistic tracing along the whole product lifecycle
- Via applications running on edge and cloud environment, value creation is done by prescriptive decisions and self-learning systems enabled by artificial intelligence (AI). Advanced analytics, machine learning and deep learning optimize product and production system efficiency and quality. Solutions can be scaled within the ecosystem to other factories

Speed
- Lead time

Flexibility
- Setup time
- Lot size

Quality
- Process Quality
- NCC

Efficiency
- Productivity
- Utilization of production

Scalability

Sustainability

Applied SAG Portfolio
- MindSphere
- MindSphere Connect
- Nanobox/IoT 2040
- Industrial Edge
- SIMATIC
- SINUMERIK
- Mendix
- Scalance

□□■ Impact on category

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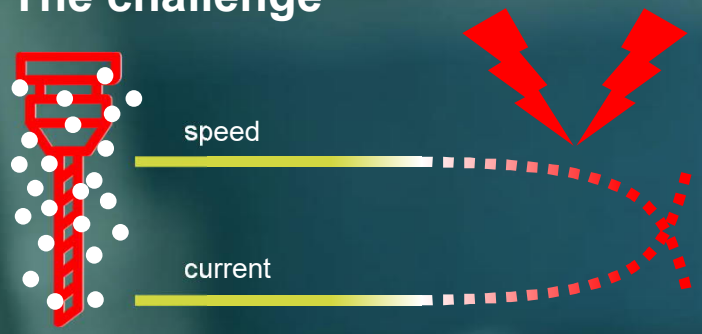
PCB cutting machine

Siemens Electronics Factory
Amberg, Germany

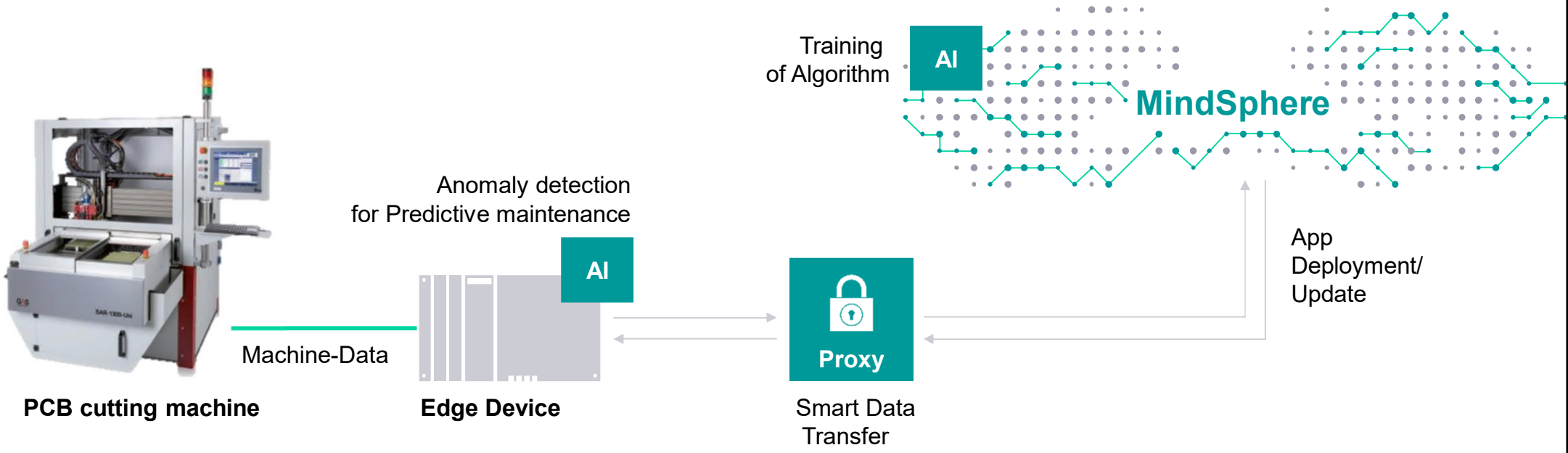
The challenge



Aggressive milling dust causes drive bearing to get stuck

Predictive Maintenance for depaneling machines

Powered by FA



AI predicts spindle maintenance for PCB cutting machine up to

2 days in advance

Reducing preliminary spindle failures of this type by

100%

Total calculated savings for 18 machines

120 Tsd. p.a.

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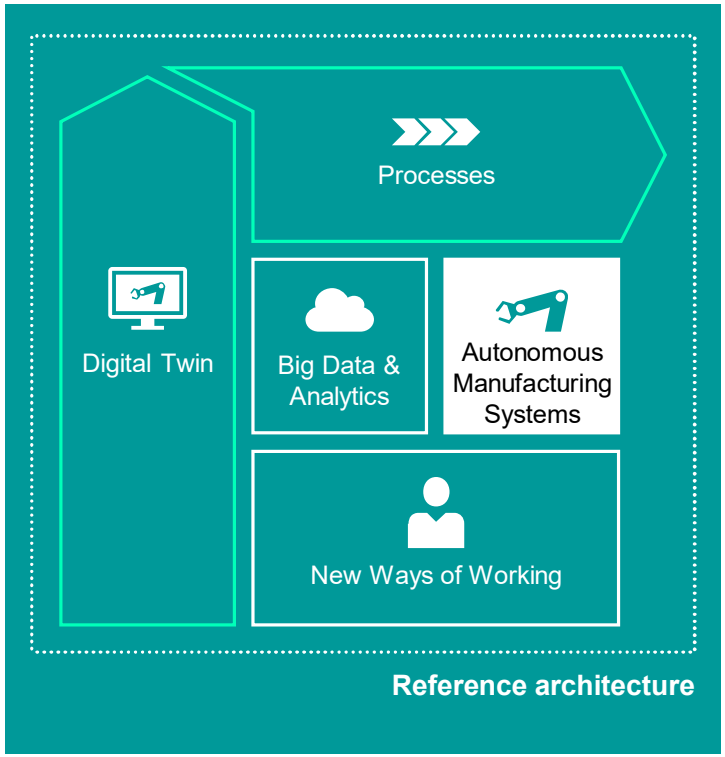
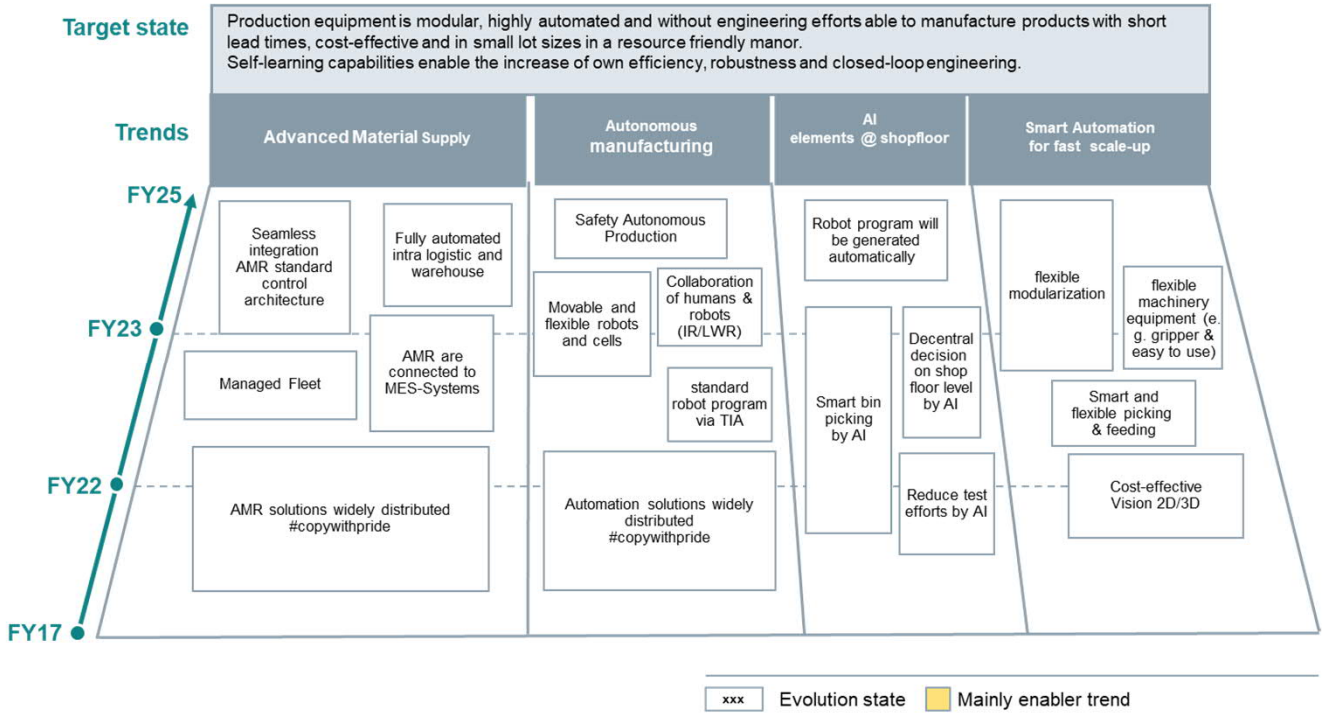
Scalable production systems raising flexibility and efficiency

Lean Digital Factory (LDF) workstreams





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Scalable production systems raising flexibility and efficiency

Digital – Autonomous Manufacturing Systems

Cooperation of digitally guided workers and interlinked autonomous production systems, enabling efficient, flexible and easy to scale-up manufacturing

- Also for low volume products and formally typical manual work the automation level is increased by modular autonomous production systems (e.g. robots). They are consisting of re-useable elements, are easy to scale-up and manufacture products with high efficiency, quality and speed. Respective machine programs are automatically generated (ARTIMINDS, Process Simulate), enabling a high flexibility and reducing manual programming efforts
- Higher operator efficiency and flexibility are facilitated by augmented reality applications, which provide workers with customized product and process information, depending on their needs and competence profiles. At the same time process quality is raised
- Managed fleets (SIMOVE) of material transport systems work seamlessly together, feeding materials directly into the production process to avoid manual material handling and raise OEE
- Based on the Digital Twins of Product and Production (provided by Teamcenter), manufacturing resources and product components are 3D printed, decreasing time-to-market and increasing production flexibility
- By permanent communication between production system agents, a flexible and efficient material & production flow is autonomously organized

Speed
- Time-to-market

Flexibility
- Setup time
- Lot size

Quality
- FPY

Efficiency
- Output efficiency
- OEE
- Engineering effort

Scalability

Sustainability

Applied SAG Portfolio
- Teamcenter
- Process Simulate
- Plant Simulation
- ARTIMINDS
- SIMOVE

Impact on category

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Challenge
Box handling with lightweight robot and autonomous guided vehicle

- Pendulum boxes (coming back from the customer) to be fed back into logistic system
- Process is manual and very irregular, making the planning for workers difficult
- Implementation of a low-cost automation, using an autonomous guided vehicle for pallet handling
  and a lightweight robot for box handling

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Bin Picking: Handling of chaotically supplied parts serves as enabler for further unit assembly automation

Trend: “Robotics”

Before

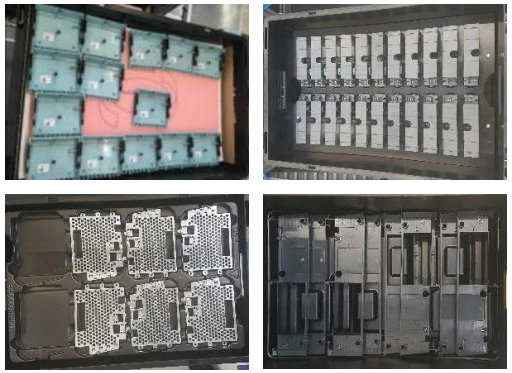
Monotonous, time- and cost-intensive **manual sorting of chaotically supplied parts** for automatic handling by the robot

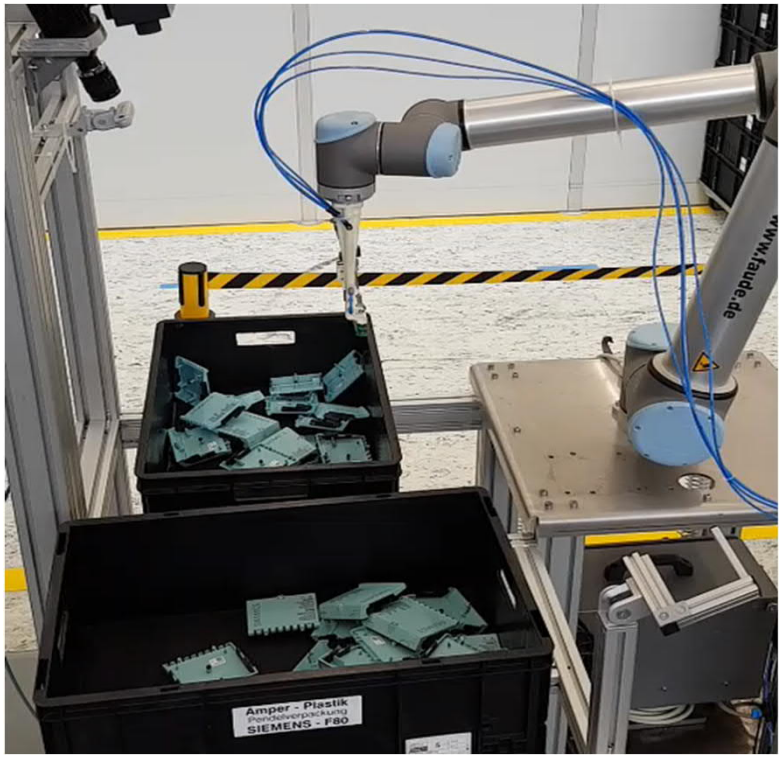
Now

Decentral integration of **cost-efficient bin picking systems** directly into the assembly station

The solution developed in the GWE is currently being transferred to the EWA

(turntable HMI)





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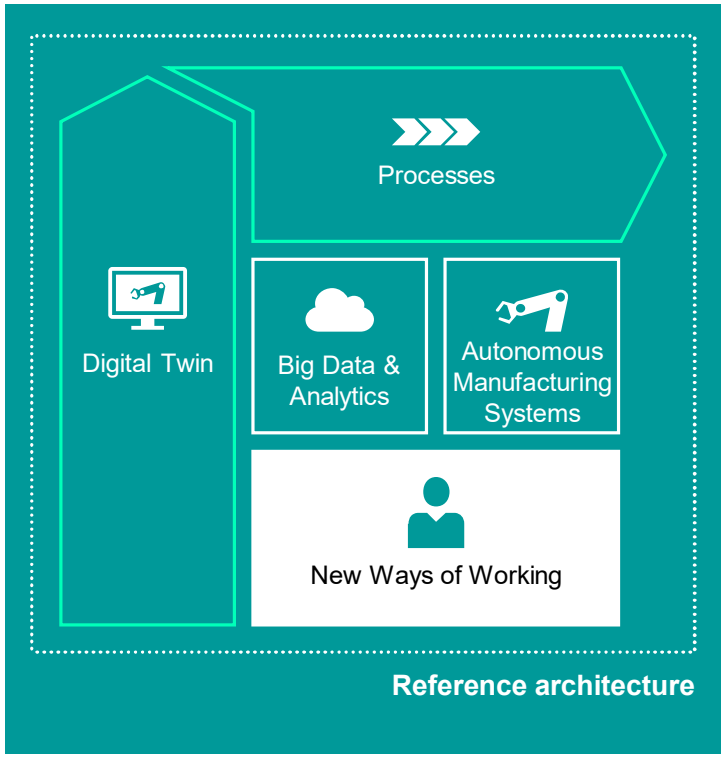
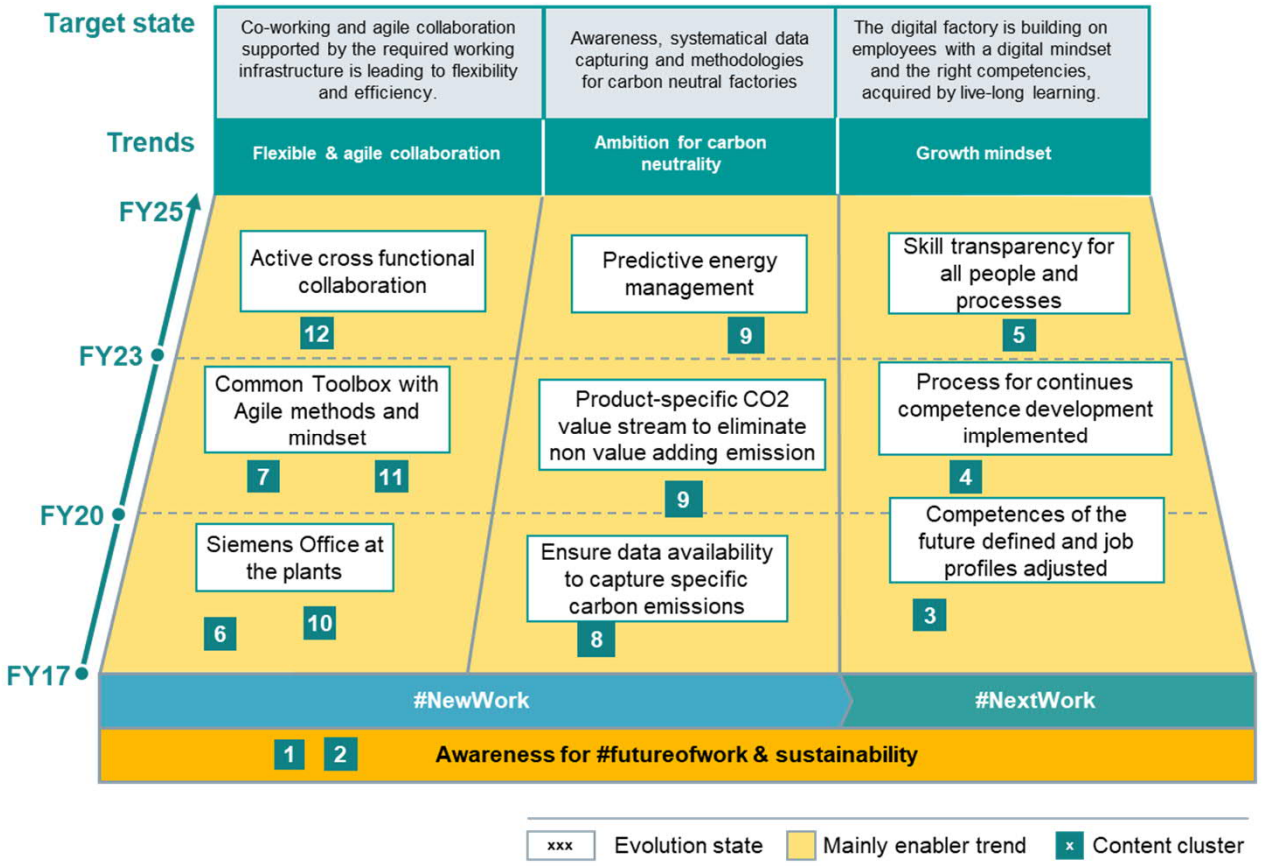
Connected workers applying new working methods in agile organizations to raise flexibility, efficiency and sustainability

Lean Digital Factory (LDF) workstreams





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Connected workers applying new working methods in agile organizations to raise flexibility, efficiency and sustainability

Digital – New Ways of Working

Live-long learning employees with digital mindset apply new ways of working, increasing the flexibility and efficiency of digital and sustainable factories of the future

- The digital factory is building on employees with a digital mindset and the right competencies, acquired by live-long learning. Co-working and agile collaboration supported by the required working infrastructure (from office concept till payment system) is leading to flexibility and efficiency
- The cross-functional collaboration in a digital factory is based on trust, reliability and openly shared information in communities and networks. In addition they are facilitated by digital office and shopfloor management. Employees are encouraged to experiment by using agile methods to learn fast and increase speed
- Employees have a growth mindset for dynamic self-organized learning, to secure own employability. Transparent, future oriented competence overviews give orientation for live-long learning. Skill transparency is a conception of oneself, beneficial for all people, organizations and processes
- Having the courage to experiment and growing on the results, employees drive digitalization and eliminate waste in processes and energy consumption in own environment, using e.g. low-coding tools especially for process automation

Speed
- Time-to-market

Flexibility
- Employee flexibility regarding tasks, time and competence

Quality
- Process quality (e.g. in development projects)

Efficiency
- Engineering effort
- Process efficiency
- Competence management

Scalability

Sustainability

Corporate SW/Initiatives
- Yammer
- Circuit
- MyLearningWorld
- Siemens Office Concept
- Siemens OnePhone
- iDea. Company tools

Impact on category

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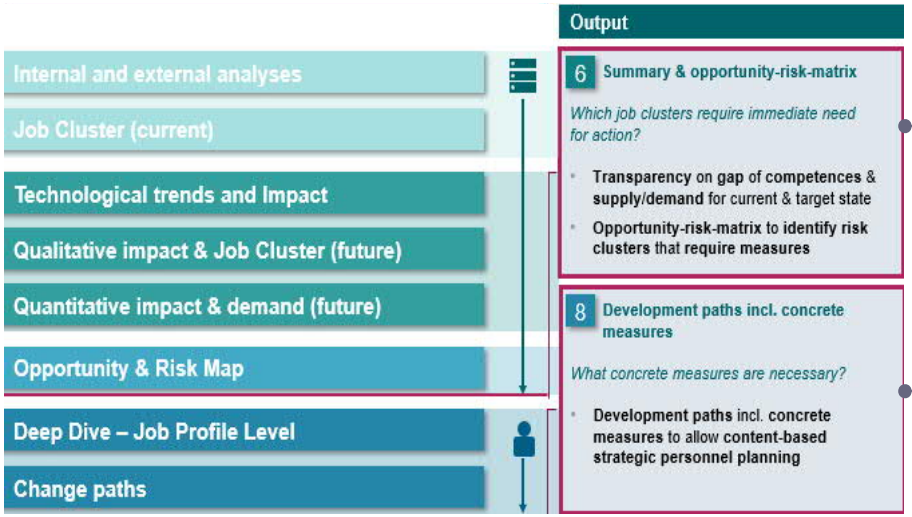
#Next Work pilot@EWN conducted and rollout within DI MC already started

Holistic approach to strategic personnel planning & competence development

Input Business Strategy

- Vision/ Mission
- Core/Non-Core
- Markets
- Business Model
- Footprint
- Portfolio
- …

#NextWork



Which job clusters require immediate need for action?

Which measures are required per job profile?

Strategic personnel planning

- Proactive, forward-thinking **planning** of measures to address **future job demand**
- Based on **business strategy**

- Trainings
- Qualifications
- Apprenticeships
- Recruiting (external/ internal)
- Footprint measures (Outsourcing, near-/offshoring, restructuring)

#NewWork – Accompanying measures DI MC

Development of agile organizational forms and establishment of new ways of collaboration

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Holistic up- & re-skilling development journey

From skilled shopfloor employee to complex machine maintainer

Technological Trends

- Automatization & robotic
- Substitution of physical and routine tasks
- Digitalization, Big Data and Analytics
- Predictive maintenance
- New ways of working

Development Path

- TIA: SERV1/2, S7 (lateral entry)
- KUKA: Robotic Operations PRO, Service & Electric, Malfunction & Maintenance
- Profibus Engineering
- NC controls & dives
- Pnoz-Multi programming & service
- MindSphere Basis
- Basis in Cyber Security

Skilled Shopfloor Employee

- Machinery handling and controlling
  - Tool setup
  - Process parameter monitoring
- Product assembly
  - Following defined order instructions

1 2 3 4 5 6 7 8

Future Competences

- Domain expertise:
  - Manufacturing technology
  - Automatization & robotic
  - Hydraulic & pneumatic systems, drives
  - Manufacturer-specific machine know-how
- Digital & programming basics
- Analytics & problem-solving

Complex Machine Maintainer

- Mechanical & electrical maintenance and servicing tasks
- Resolving of malfunctions
- Organization of machinery transitions
- Design & setup of workplaces

Source: Project #NexWork @ DI MC

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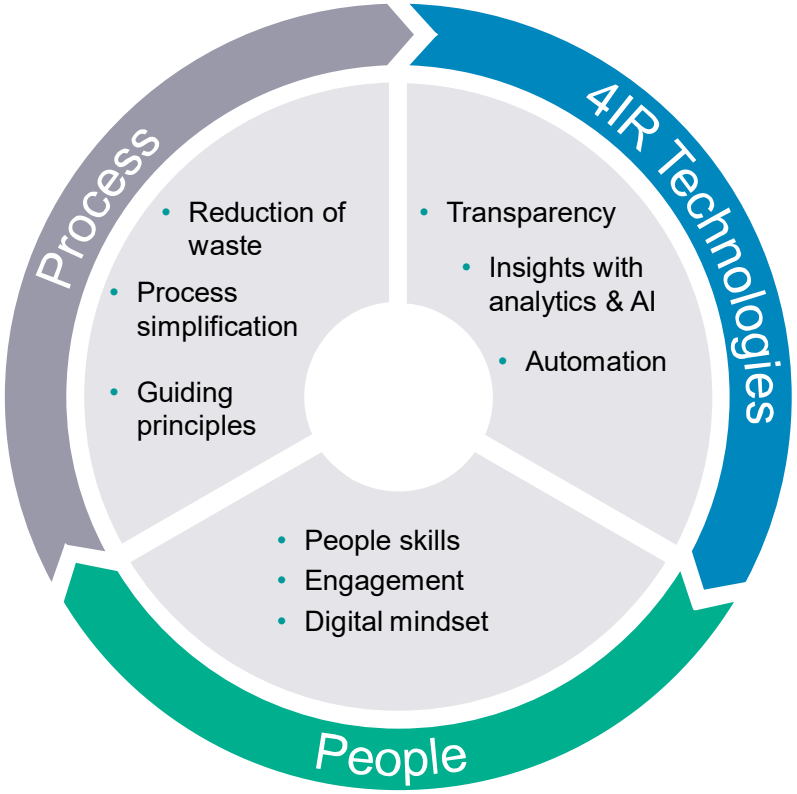
Lean production and 4IR are established in the daily operation of our factories



What is the

next challenge?

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CO_2

Carbon

footprint?

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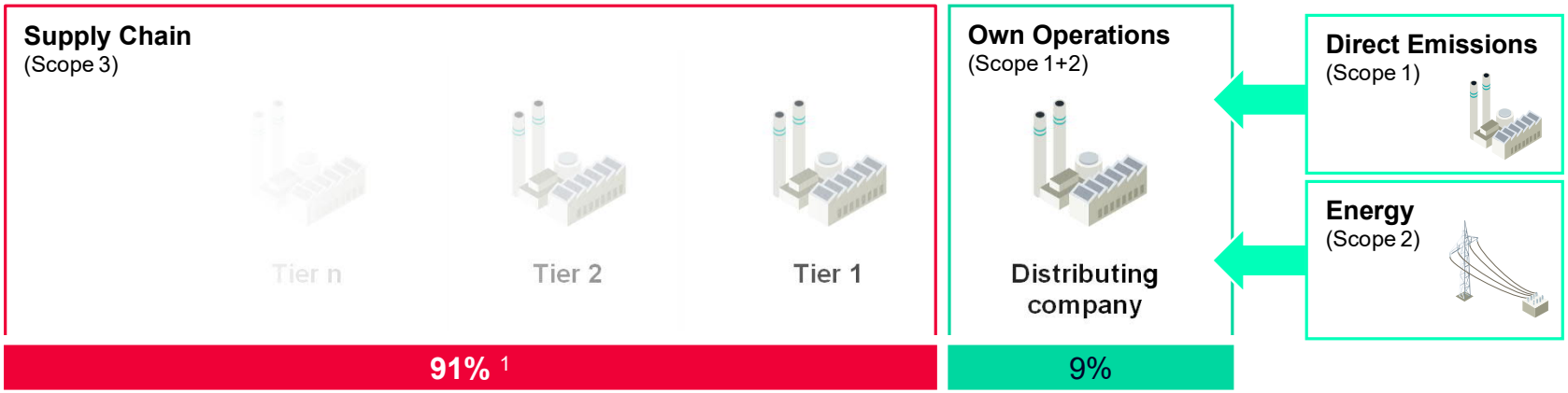
Requirements on accountability for PCF are increasing but more than 90% are in the supply chain and not transparent



*"**Reliable, comparable and verifiable information** plays an important part in enabling buyers to make more sustainable decisions. Companies making "green claims" should substantiate these against a **standard methodology** to assess their impact on the environment.*

The European Green Deal
European Commission, Brussels, 2019

1 Carbon Disclosure Project, Feb 2021

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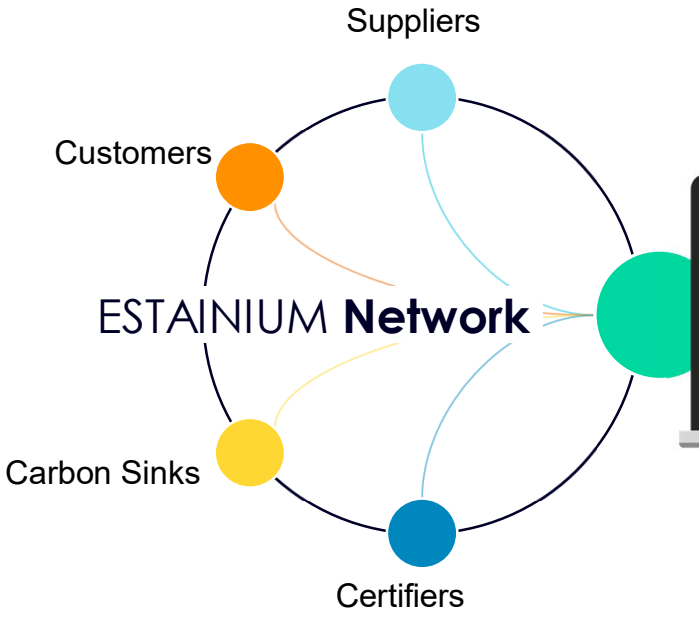
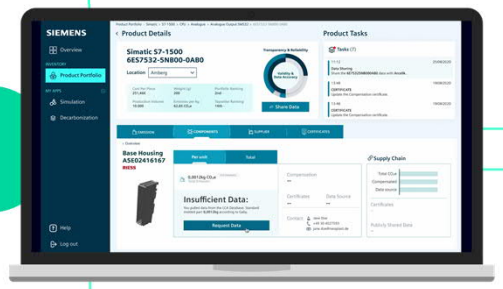
As a gateway to the independent ESTAINIUM Network Siemens Provides SiGREEN web and SiGREEN connect[1]



SiGREEN web

- Requesting, calculating and sharing trustworthy PCF data
- Uploading of BOM
- Convenient onboarding of suppliers via web frontend for standardized data input



SiGREEN connect

- SiGREEN web features **plus**:
- On-premise or private cloud with IT and OT integration, e.g., factory energy metering and ERP systems
- Automated footprint sharing and calculation

independent | open | cross-industry

Leveraging Siemens' industry expertise

1) Other companies are invited to develop their own gateways to the ESTAINIUM Network

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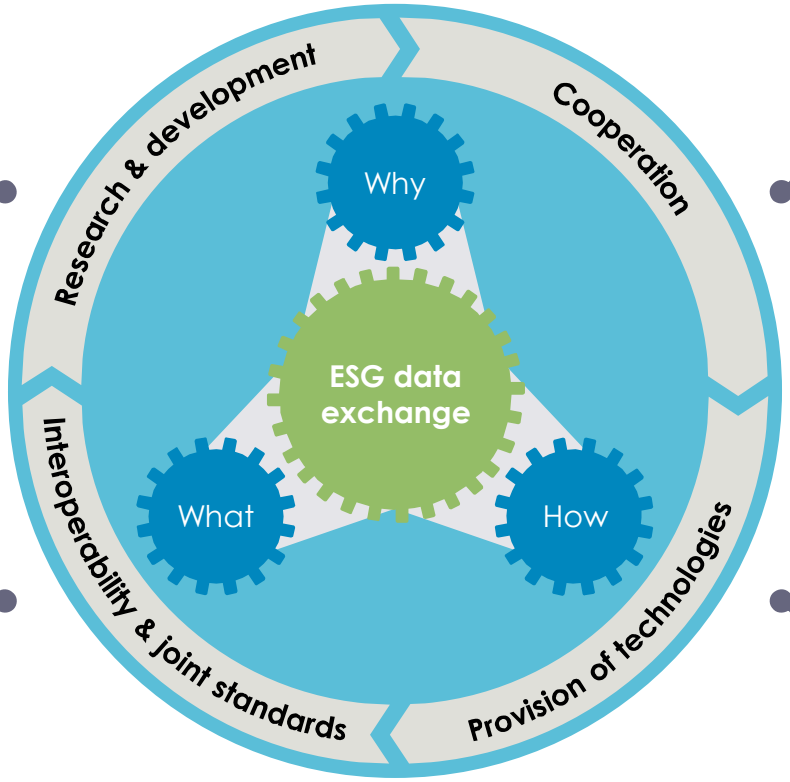
ESTAINIUM
Association

The ESTAINIUM Association

Education of **stakeholders** on use cases of inter- and intra-company execution of sustainability

Involvement in the **development** of **international standards** on sustainability

Alignment on **common principles** to allow for **interoperability**



Alliance of sustainability **thought leaders** across industries, NGOs and certifiers

Governs the ecosystem as an **independent cross-company** body

Initial **tech-stack** donated as **open source** by Siemens to kick-start activities

LDF
Lean Digital
Factory

Dr. Gunter Beitinger

SVP Manufacturing,
Head of Factory Digitalization &
Product Carbon Footprint

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