SYSTEMA
Art of Automation

20th Innovation Forum for Automation

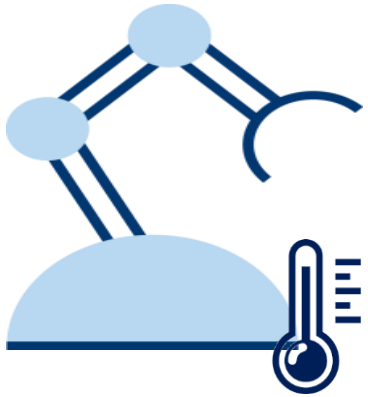
Optimizing semiconductor production using AI and scheduling to balance competing goals

Dr. Holger Brandl
Analytics Solution Architect
27.1.2023

AISSI
AUTOMATED SCHEDULING

https://aissi-project.com

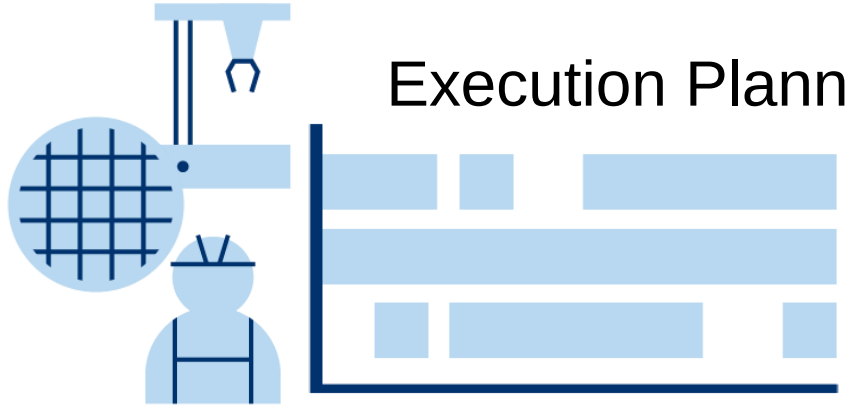
AI Potential in Manufacturing



Predictive Maintenance

Predictive Quality

Factory Health & Anomaly Detection

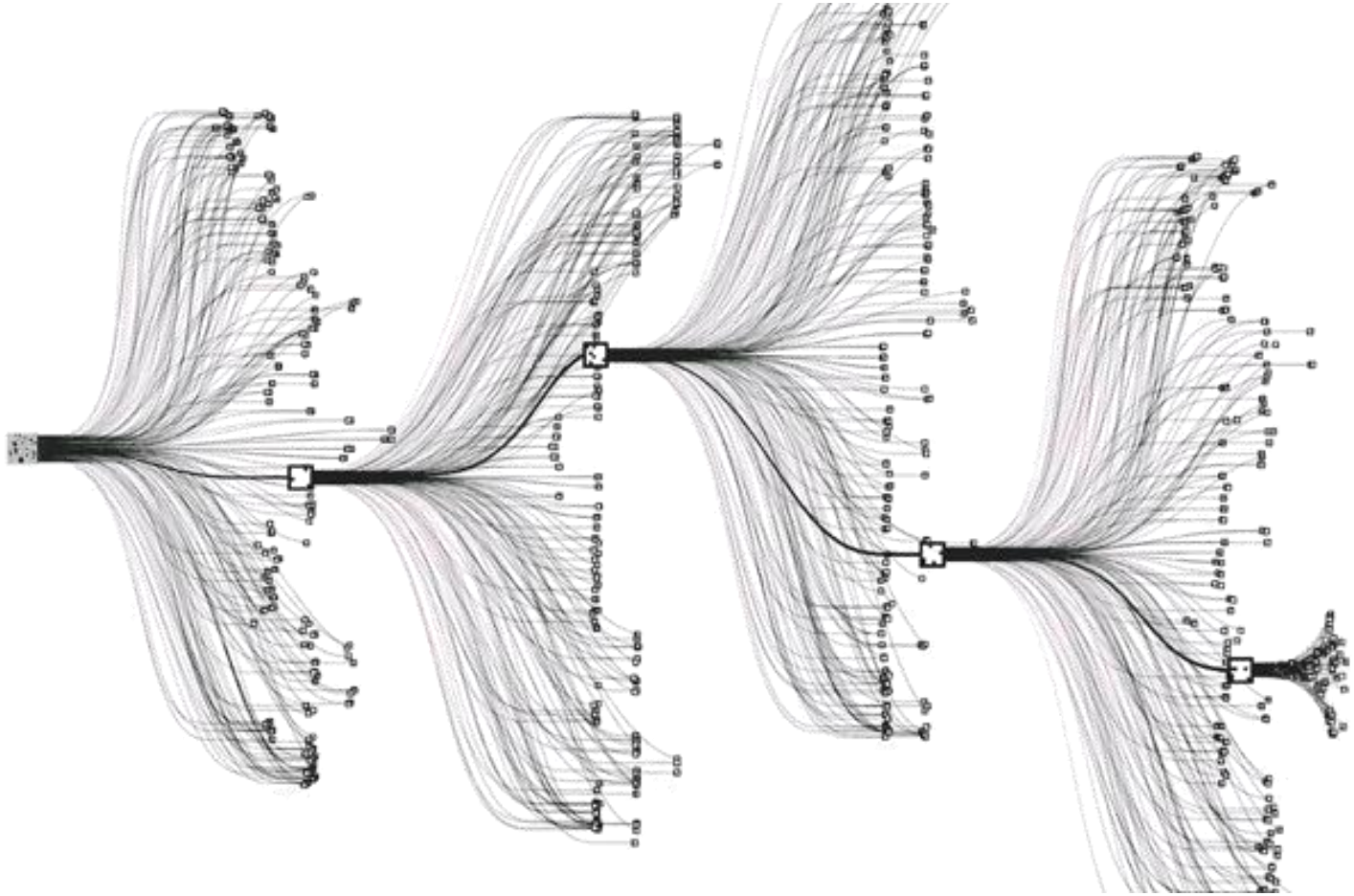


Execution Planning

SYSTEMA Art of Automation

Challenges of AI in Manufacturing

- Search space complexity
- Problem formulation
- Non-rectangular data
- Lack of training data
- Often no steady state
- Product mix leads to many models
- Many shopfloor unicorns
- AI ownership and model maintenance
- Unclear return on investment



Autonomous Integrated Scheduling for Semiconductor Industry

AISSI AUTOMATED SCHEDULING

ITEA 4

Bundesministerium für Wirtschaft und Klimaschutz

Enterprise Singapore

nexperia

SIMLAB Technologies

KIT Karlsruhe Institute of Technology

BOSCH

SYSTEMA Art of Automation

Project Lead
BOSCH

Countries
2

Partners
6

Costs
>3.4 Mio. €

Research Area
Smart Industry

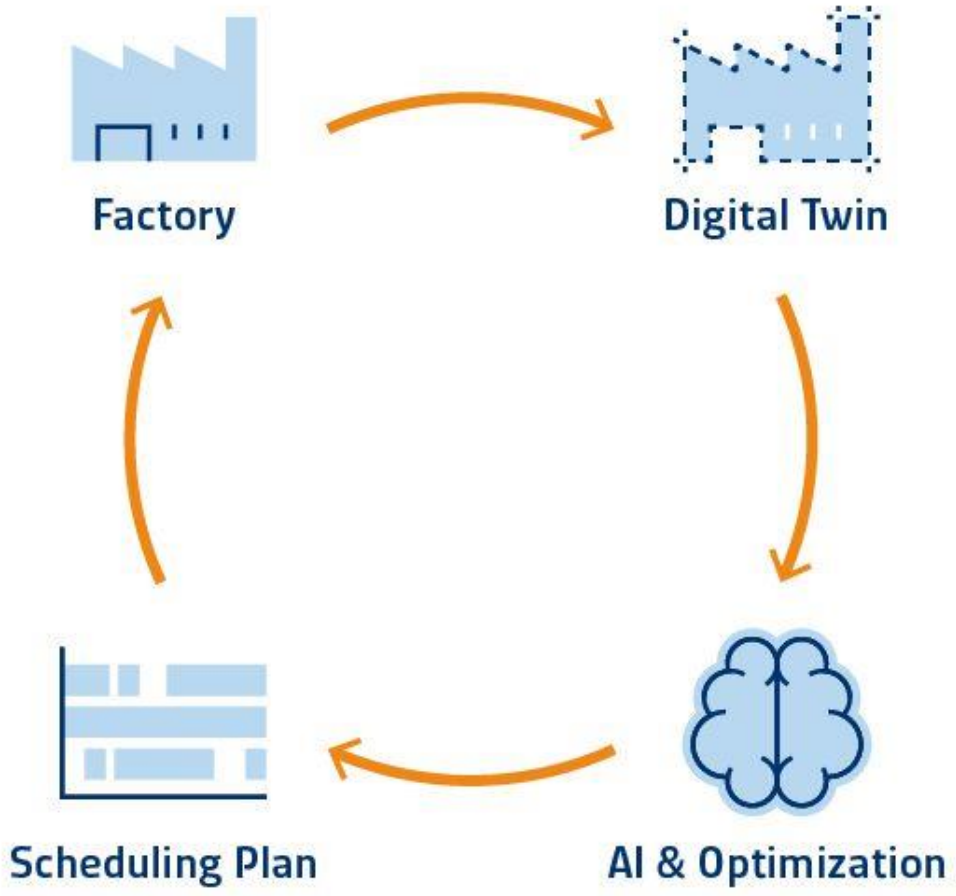
Duration
36 Months

https://aissi-project.com

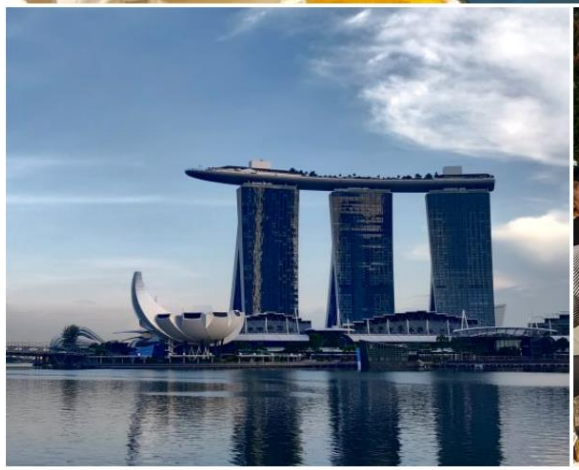
Expected Improvements

Simulated area throughput	Simulated area WIP level	Compliance to scheduling results	Cycle Time variability	Equipment utilization
15% increase	10% decrease	10-20% increase	15% decrease	1-2% increase

Enable Reinforcement Learning for Shopfloor Execution Planning



#ReinforcementLearning #AI #Simulation #Scheduling #ArtOfAutomation



You and 61 others

1 repost

Optimization Challenge

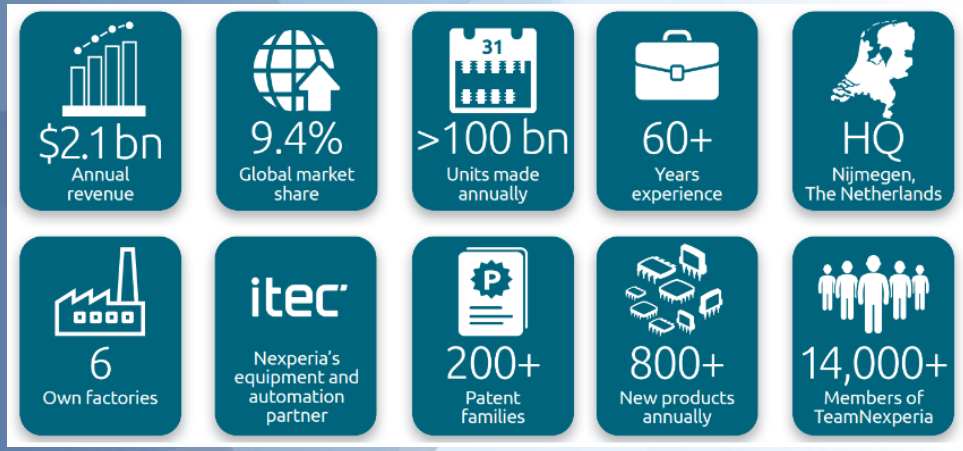
Epitaxy Production at Nexperia Hamburg

- Optimize throughput and other objectives in the epitaxy area at Nexperia Hamburg
- Initial process step for majority of flow definitions
- Epi is a rate-limiting process step

- Establish analytical model to quantify production improvements and ROI
- Improvements could be better execution planning but also other types of process changes

nexperia

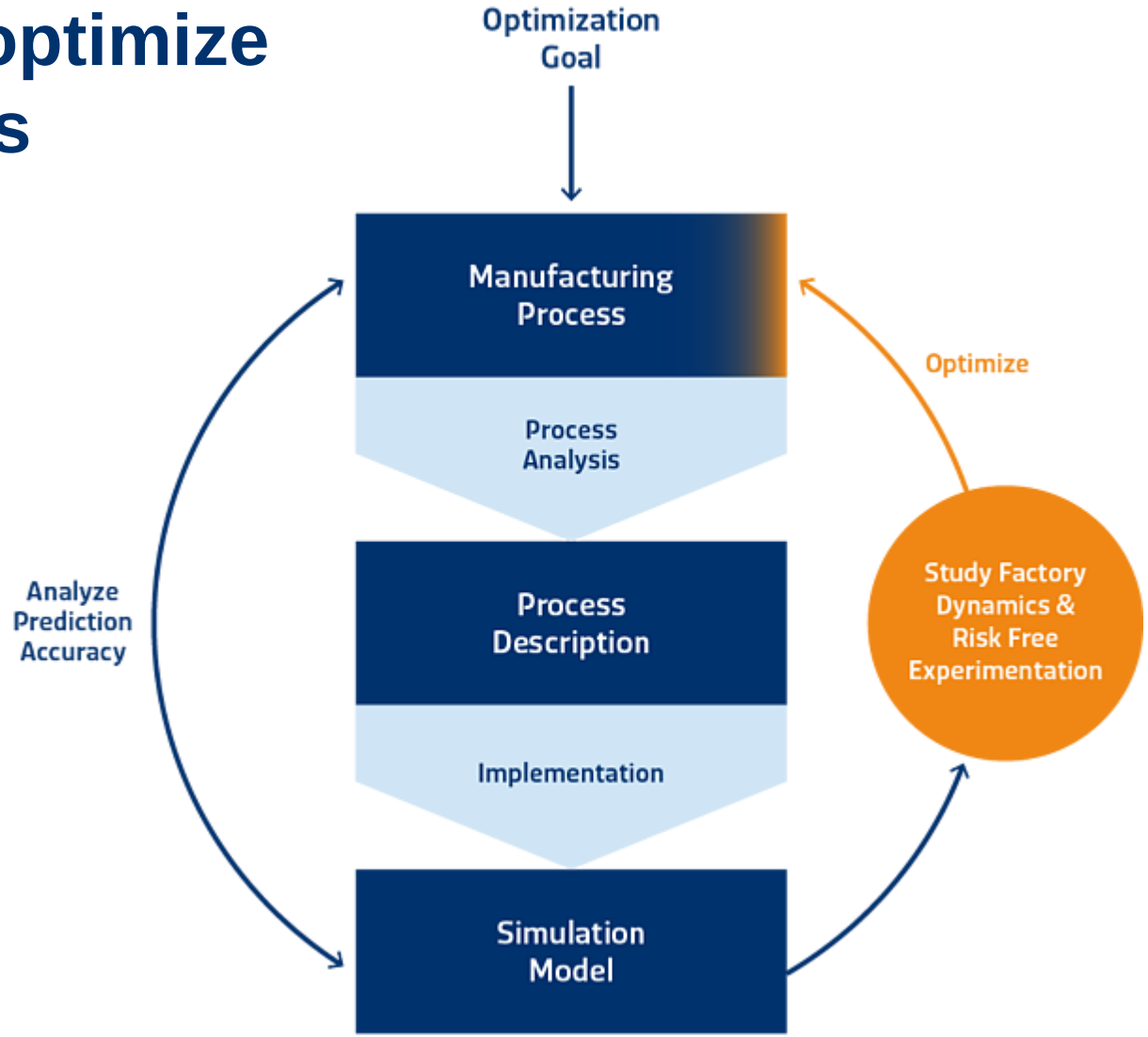
EFFICIENCY WINS.



https://www.nexperia.com/about.html

SYSTEMA Art of Automation

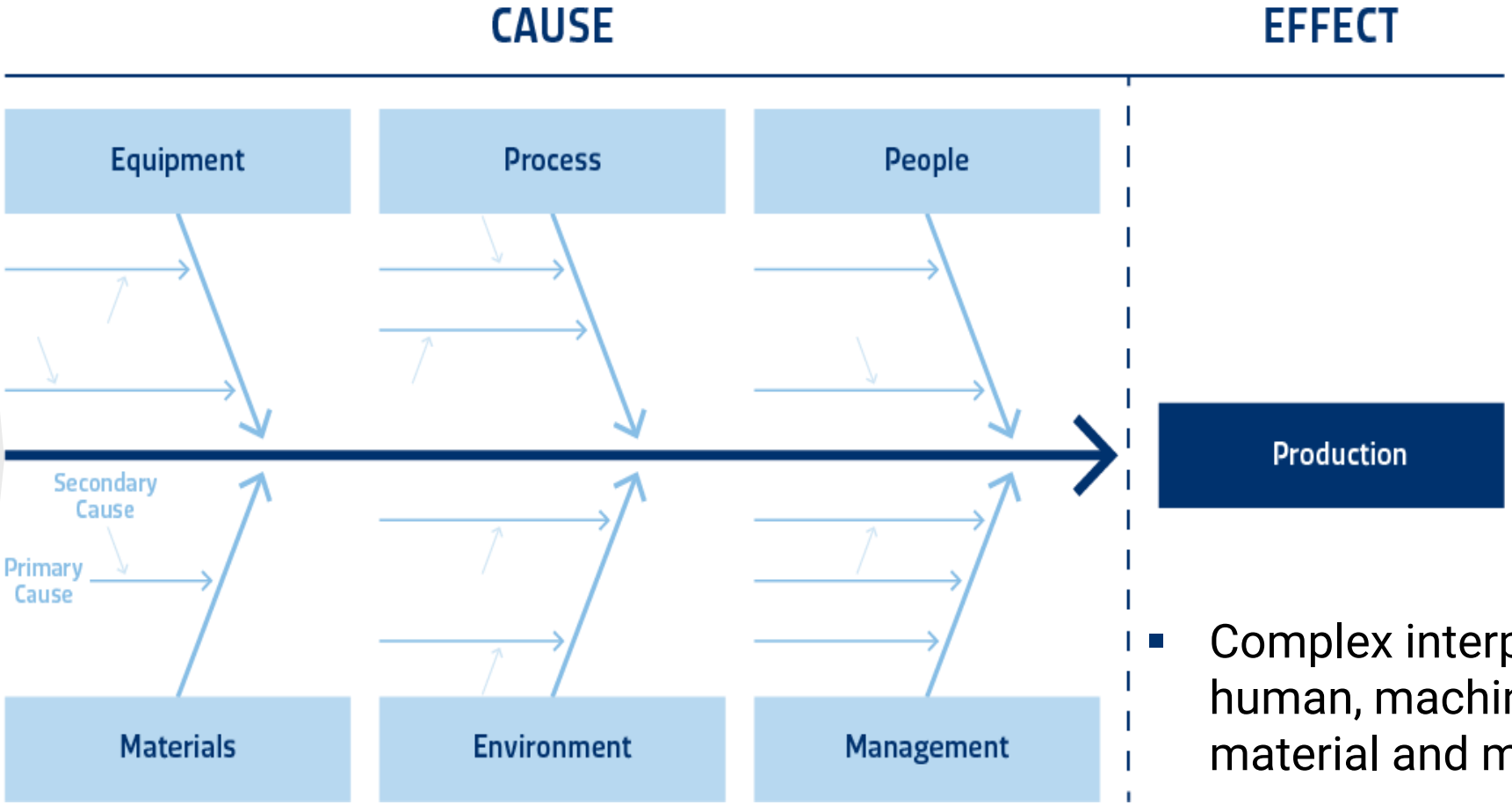
Use model-based analysis to optimize complex production processes



Study & Quantify changes to production execution using process simulation & modelling

Semiconductor Front End Operations

Material Types
Hold Status
Material Ownership
Cycle Times
Due Dates
Equipment Capabilities
Anticipated Downtimes
Equipment State
Dummy/Baffle Filler Material
Tests/Experiment Conditions
Date/Time Calculations
Downstream Resource State
Up/Downstream Inventory
Timer Expirations
Critical Ratios
Kanban
Raw Material States
Recipes
Process Times
…



- Complex interplay of human, machine, material and methods
- Not always following intuition

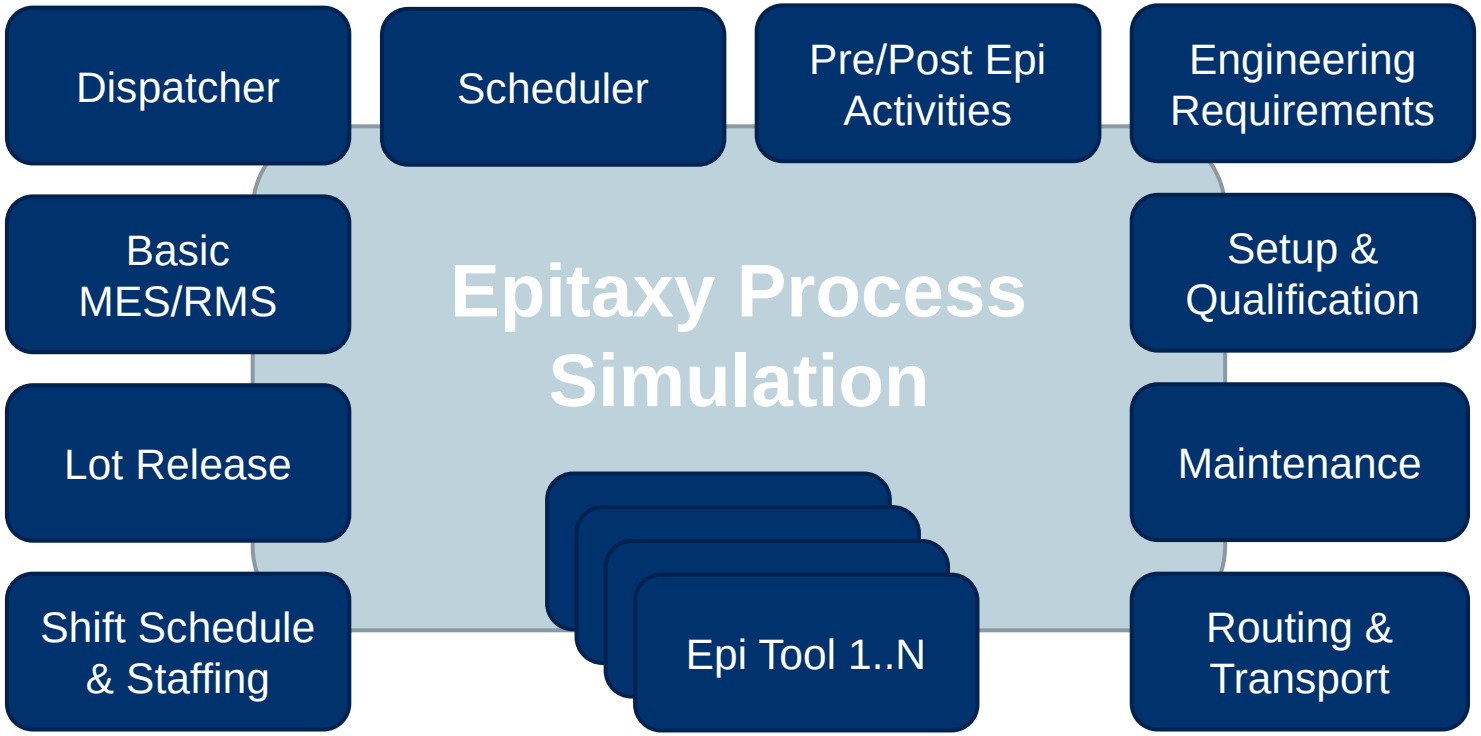
Simulation Model

Epitaxy Area Hamburg

SYSTEMA
Art of Automation

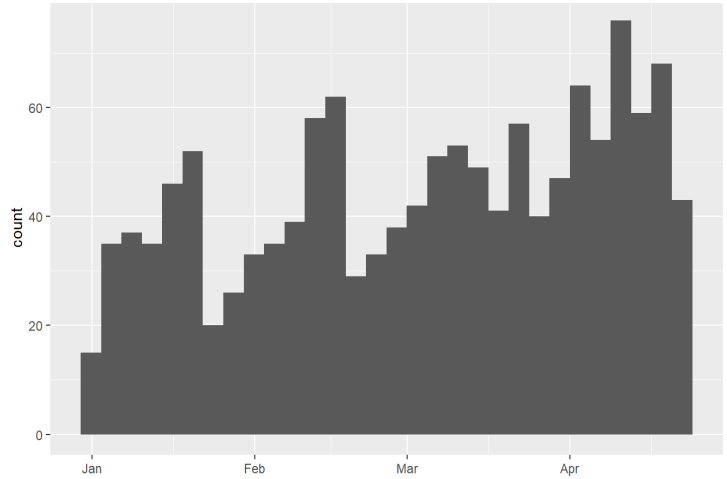
Epitaxy Process Simulation

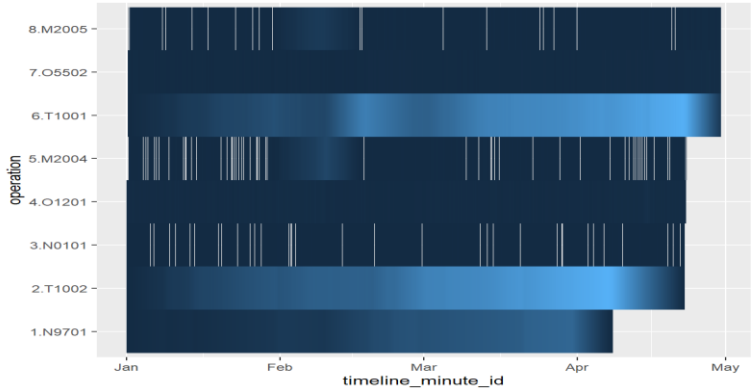
- Parametrized using various data snapshots from MES, ERP & shopfloor

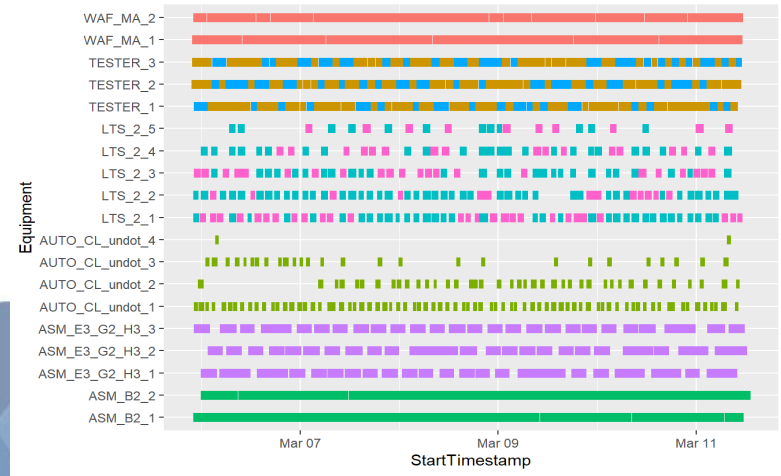


SYSTEMA Semiconductor Frontend Simulation Toolbox

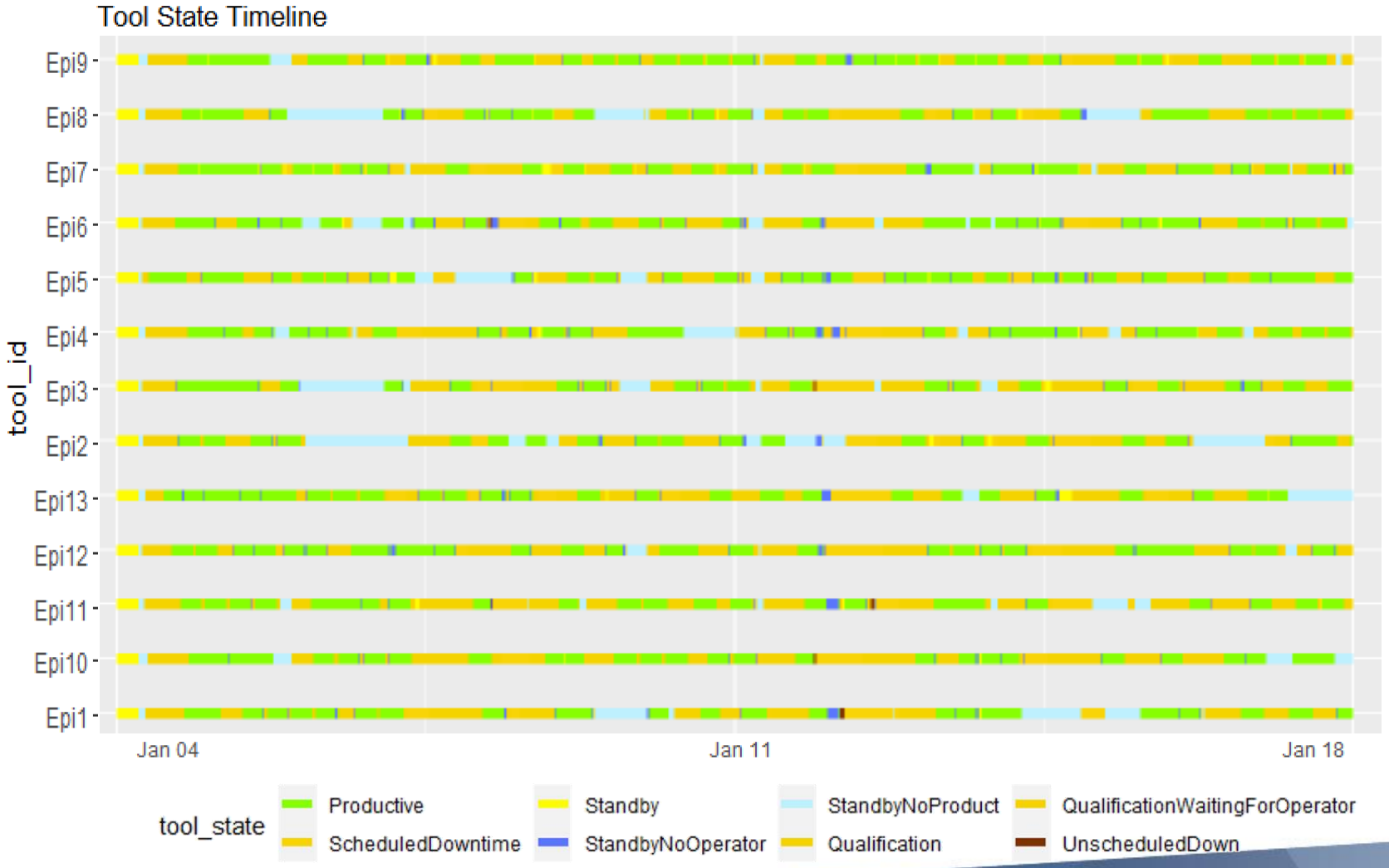
- Discrete-event Frontend fab simulation model
- Realistic flows (cyclic routes, split/merge, rework, scrap)
- Lot & Tool granularity (with options for abstraction)
- Qualification (Stochastic, Rule-Based, Expiration)
- Tool properties (rates, load ports, batching)
- Flexible statistic and rule-based lot release
- Tool down, maintenance, personnel
- “Warm start” using material & tool state data
- Fast: simulate **years** of production **in just seconds**







Epitaxy Process Simulation: Tool State & Setup

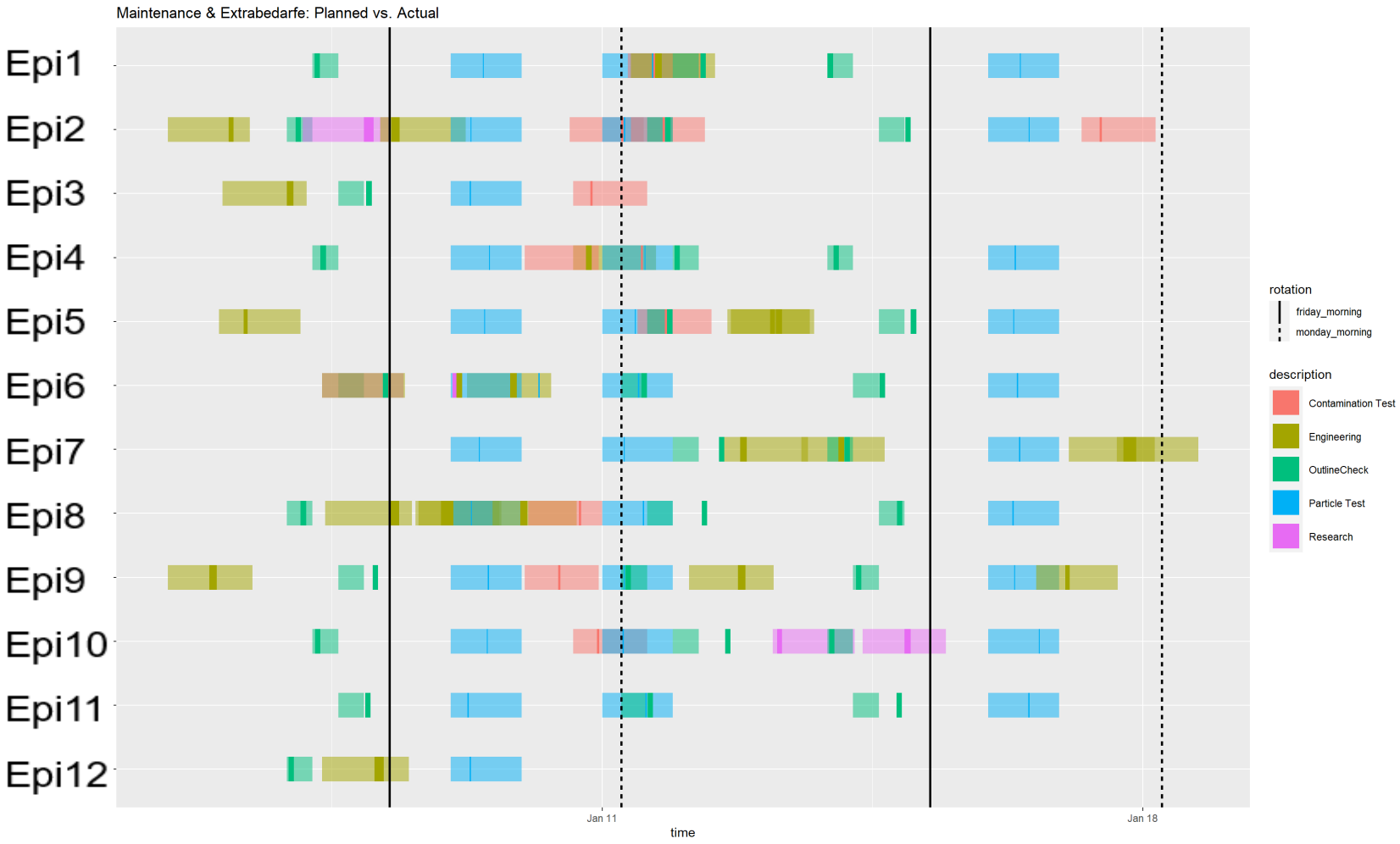


Area throughput limited by multiple resources (lot provisioning, operators, tools, maintenance)

SYSTEMA Art of Automation

Maintenance Planning

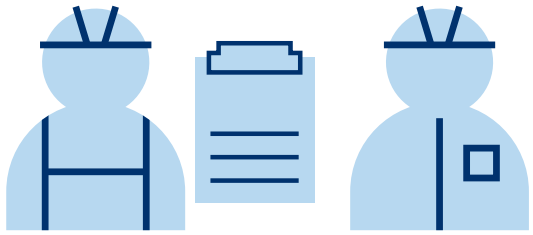
- Maintenance tasks are defined in external ERP system
- Tools loose qual if maintenance does not happen within defined time window

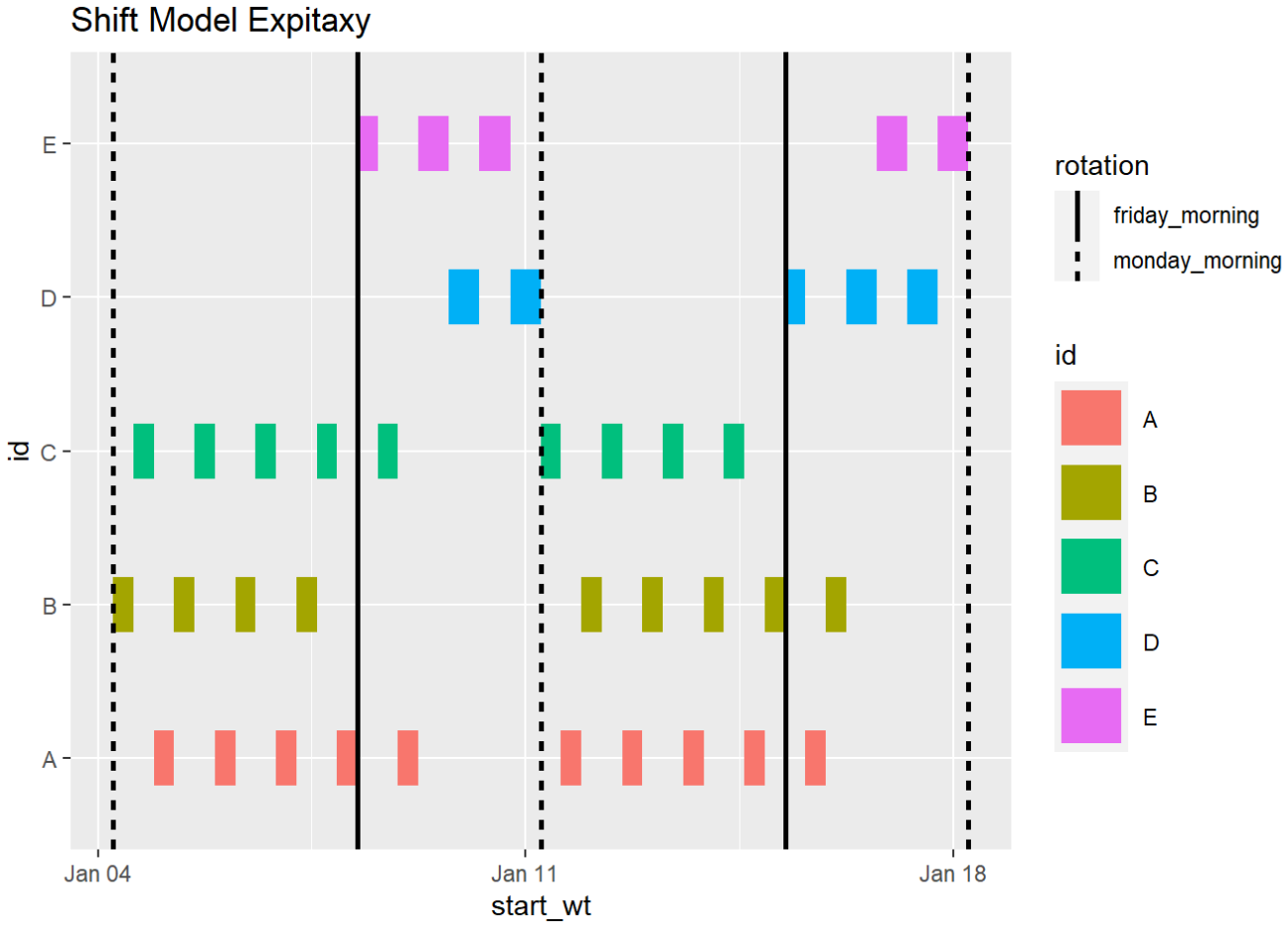


SYSTEMA Art of Automation

Put operators into the center and not machines

- Operators need to hand over area to next shift
- During shift-handover, new lots won't be started since operators are busy





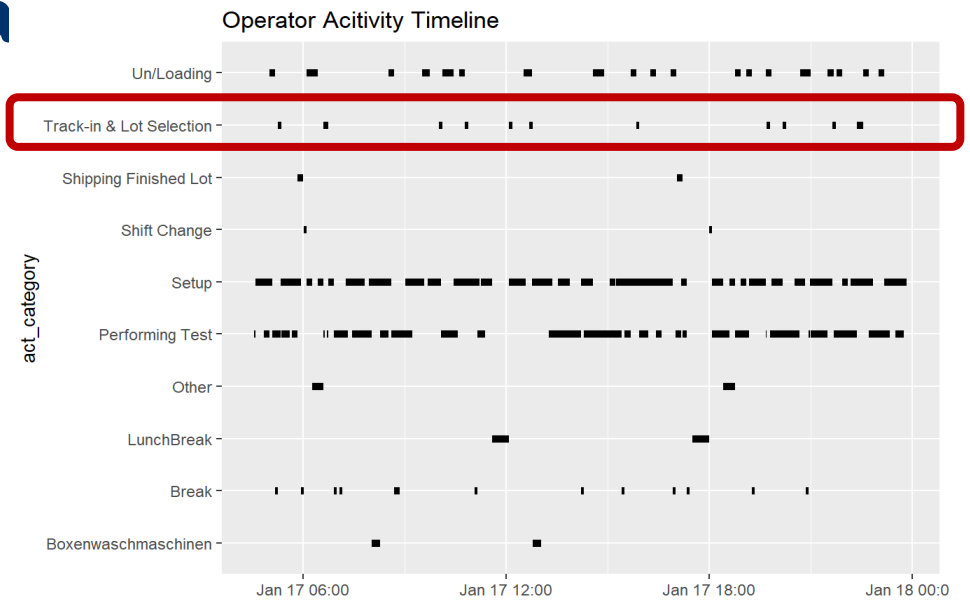
Model-Driven

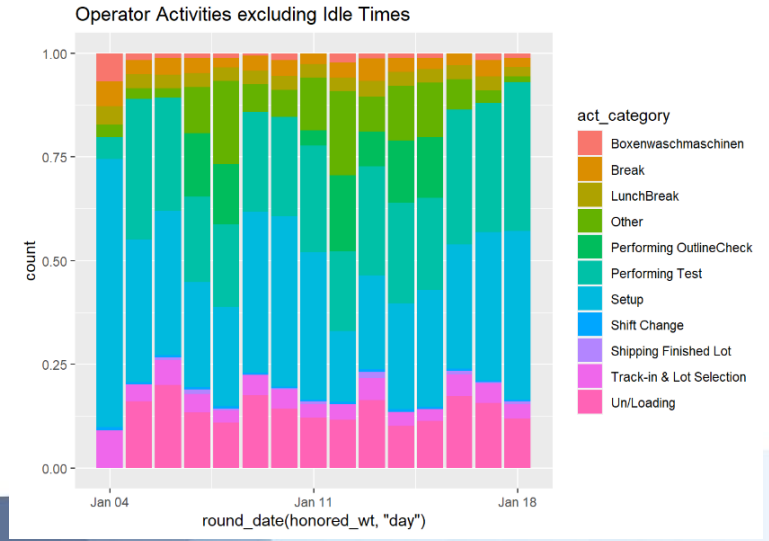
Production Optimization

SYSTEMA
Art of Automation

Operator Workload in Epitaxy Area

- Understaffed area: waiting for qual and operators are a major productivity constraint
- Detailed area model including operator activities
- ~5min spent to select next lot and to track it into MES
- What if we could streamline the operator guidance process to save just these five minutes?

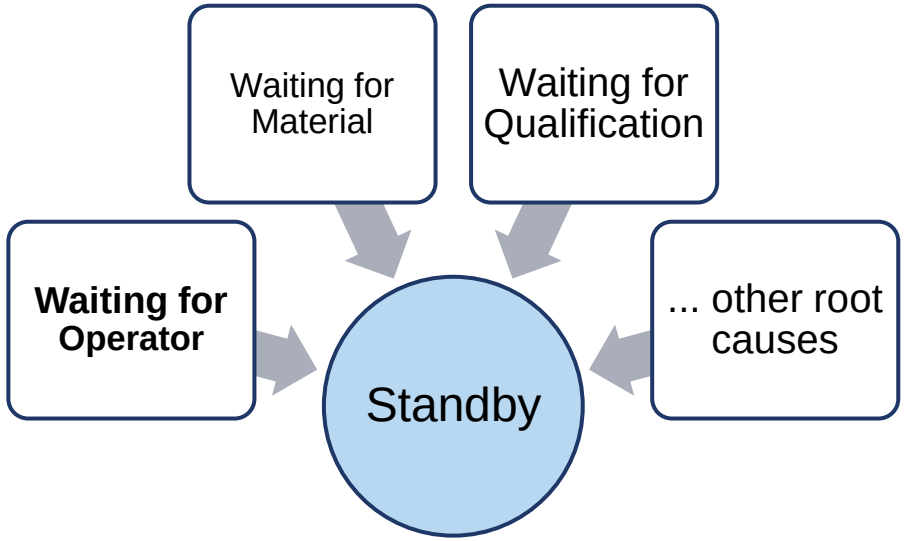


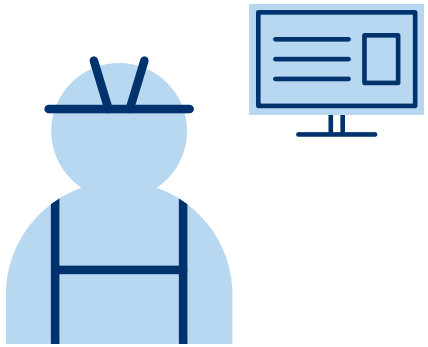


SYSTEMA Art of Automation

Optimize Bottleneck Tool Groups by Reducing Standby

- "Standby" status very present in all reference tool groups
- Multifactorial problem
- How much throughput could be gained with a simpler operator interface?
  - Fewer degrees of freedom
  - Less information



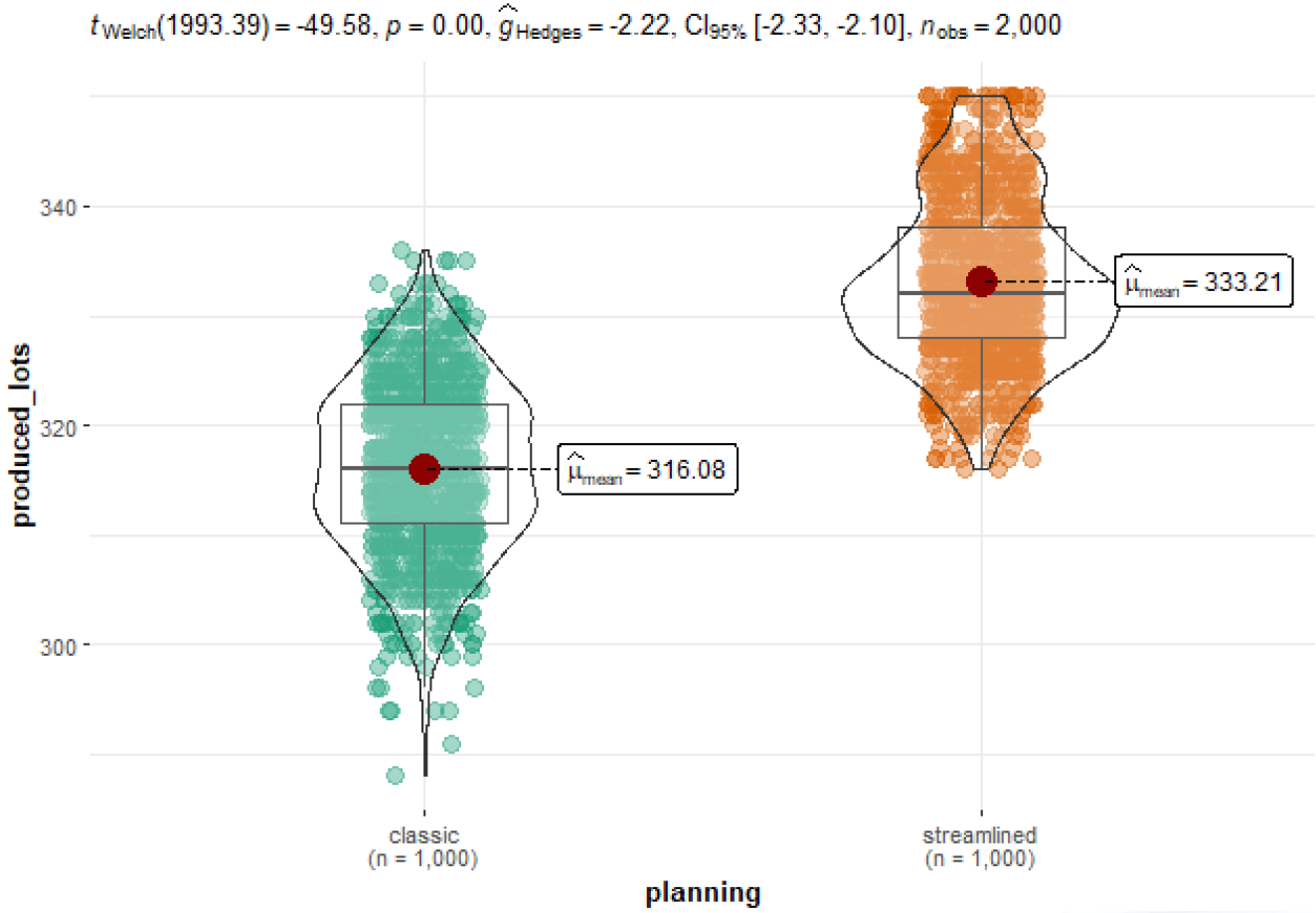


Improved Operator Guidance and Interface → +5% Throughput

Considered two simulation scenarios

- *Classic* – it takes 5 mins to select and track-in a lot
- *Streamlined* – it takes a negligible time to do so

- 14 days (with repetition)
- Significant productivity boost from better operator guidance
- Improved productivity in bottleneck areas



SYSTEMA Art of Automation

https://www.systema.com/optimization

SYSTEMA Shopfloor Scheduler

- AI constraint solver
- Based on lightweight, embeddable planning engine
- Extensions for 4M semi-production optimization (Staffing, Material, Routes)
- Over-constrained planning
- Continuous, event-driven planning
- Planning entity pinning
- Multi-stage planning

Optimization Goals: Epitaxy Process @ NEXPERIA

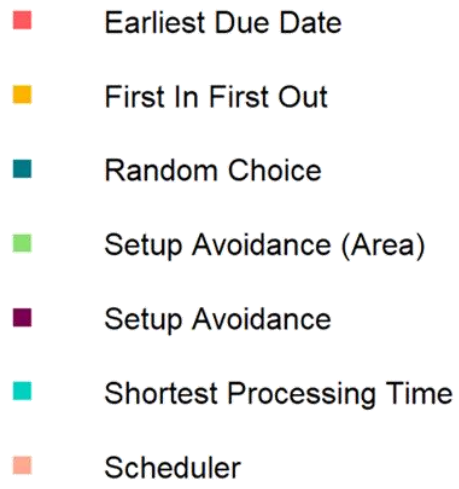
- **Task Assignment Uniformity:** Maximize and level tool utilization within tool group
- **Minimize Set Up:** Consider tool setup state when building schedule
- **Shift Hand Over Overlap:** Tasks should not start during a shift handover period
- **Minimize Cycle Time:** Schedule tasks as early as possible
- **Ensure Due Date Compliance:** Make sure lots are finished before their due date
- **Minimize Material Transport:** Consider shelf-location when scheduling lots to tools

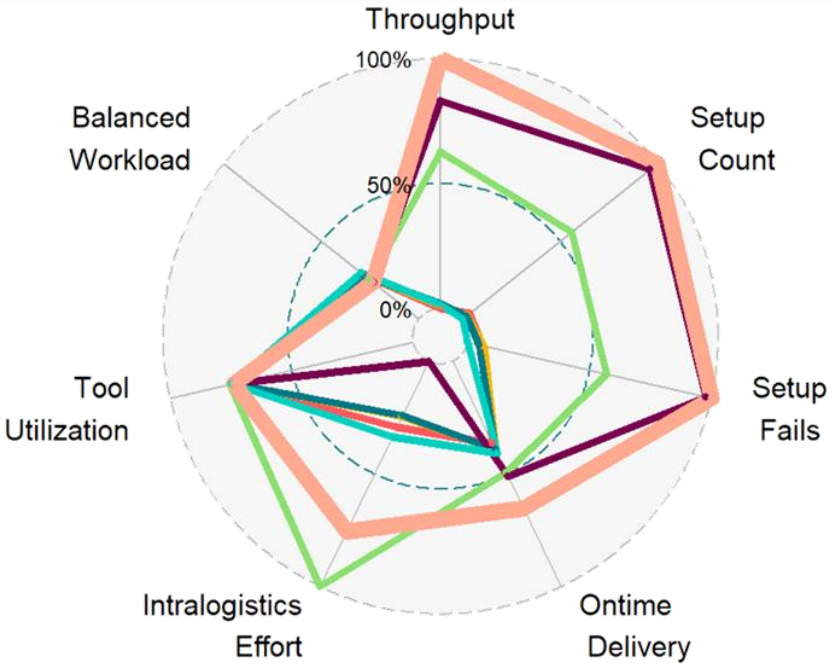
→ Balance conflicting production targets

→ Complex cost function with constraints

Planning Method Performance Analysis

- Scheduler outperforms baseline dispatching rules with respect to all key metrics
- Maximization & Balancing of production targets via integrated cost function
- Configurable by user
- Continuous benchmarking using current product data



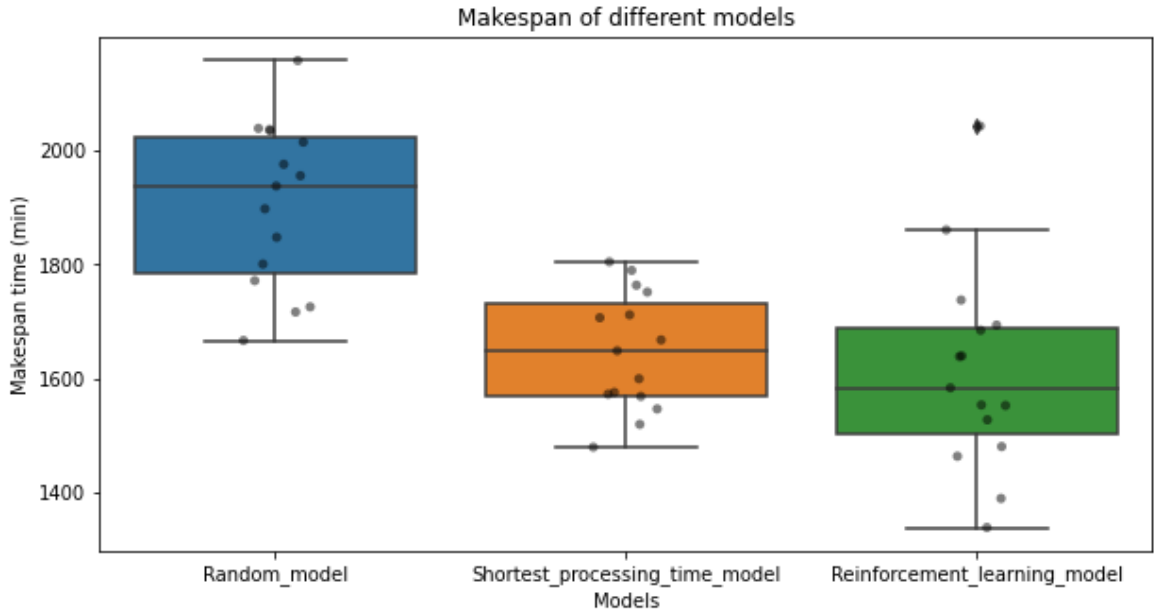


First Results: Reinforcement Learning Planning Agent

- Only assessed very small WIP configuration
- Poor generalization
- Not all optimization requirements of Nexperia could be modelled with the RL agent

Ongoing Research with AISSI Partners

- Suitable problem formulation
- MCTS compute requirements
- Unclear AI Ops Process & Roles



AIMS 5.0 - Improve applicability & sustainability of AI in manufacturing

- 53 partners in 12 countries
- Approved by BMWK in 01/2023
- Starting in spring 2023

Vision

- Ease use of AI tools & methods
- Increase production efficiency with AI
- Improve sustainability using AI

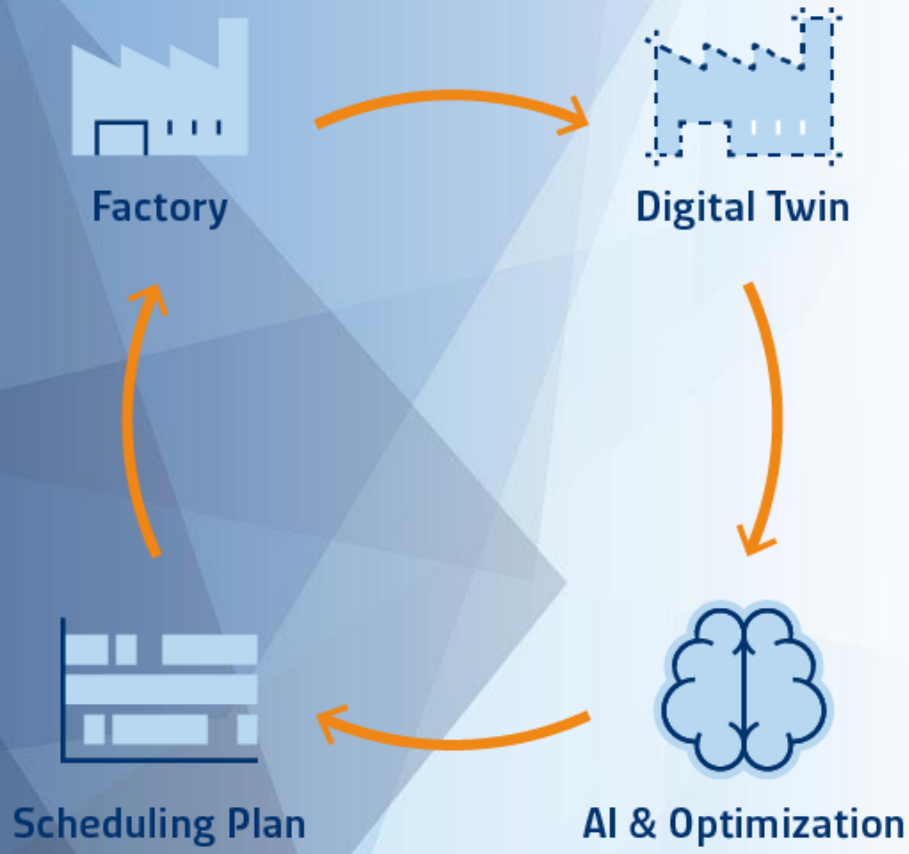
Bundesministerium für Bildung und Forschung

Freistaat SACHSEN

Copyright © Infineon Technologies AG 2022. All rights reserved.

Optimizing semiconductor production using AI and scheduling to balance competing goals

1. Establish analytical process
   → **Process Analytics & Modeling**
2. Improve execution planning
   → **Scheduling & Dispatching**
3. Squeeze all the juice from the precious orange
   → **Enable AI on the shopfloor**



SYSTEMA
Art of Automation