

# ASSISTANT SE Case Study

**Helmut Simonis**

## Constraint Based Production Scheduling

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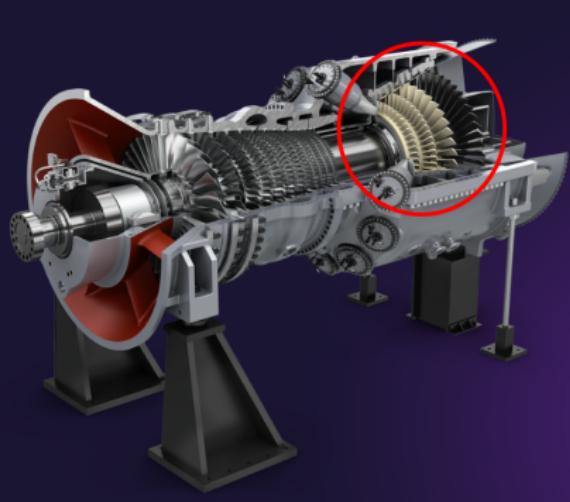
Part of this work is based on research conducted within the ASSISTANT European project, under the framework program Horizon 2020, ICT-38-2020, Artificial intelligence for manufacturing, grant agreement number 101000165.

# Key Points



- Scheduling/Planning tool for manufacturing industry
- Developed as part of European ASSISTANT project
- Focused on key make-or-buy decisions
- Complex manufacturing process with alternative process paths
- Outperforms both current in-house tool and commercial simulator
- Key Technology: Optimization and Constraint Programming

# Assistant Siemens Energy Use Case



The image shows a detailed 3D cross-section of a gas turbine engine. The engine is mounted on a stand and features a red circle highlighting the compressor section, which is located at the front end of the machine. The internal components, including the compressor blades, stator vanes, and turbine sections, are visible through the cutaway.

### Use Case Scenarios

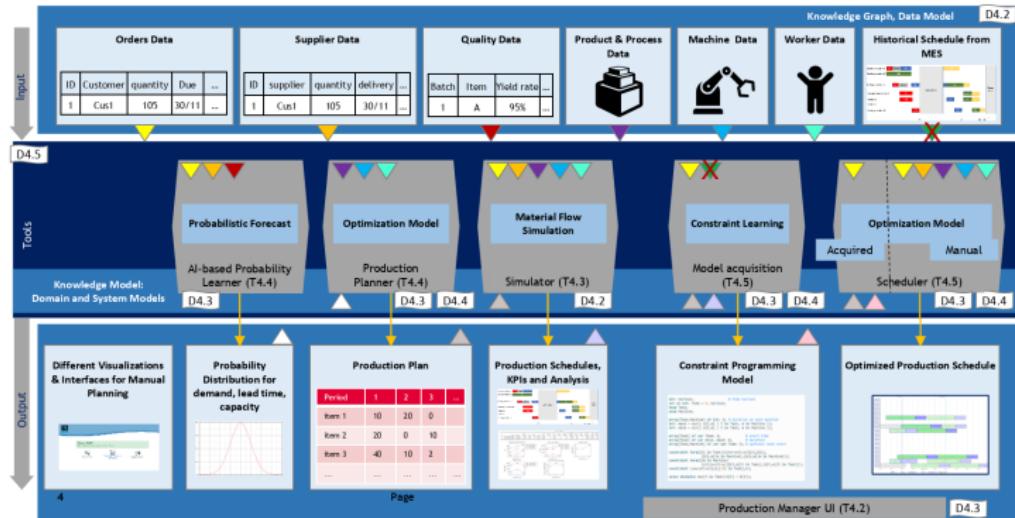
- Schedule *validation* of gas turbine blades and vanes manufacturing operations in Berlin plant
- Schedule *optimization* to manage short-term, mid-term and long-term load fluctuations
- Generate *Make-or-Buy proposals* for workload balancing within the manufacturing network

# ASSISTANT Project Overview

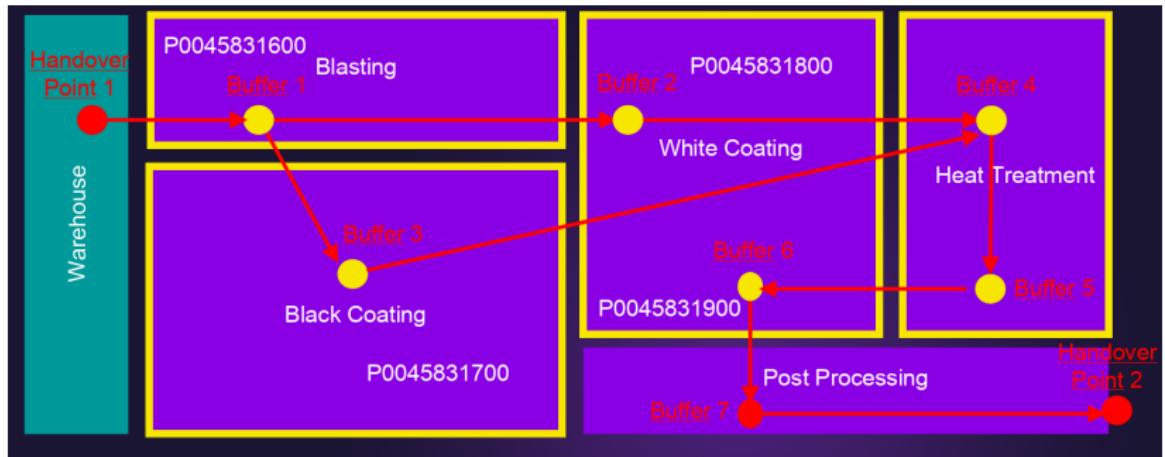


Intelligent digital twin for process planning and scheduling

ASSISTANT



# SE Product Routing



# Test Datasets



## Full Scale Datasets

Berlin06: 96 orders, 9 months horizon, previous review



Mon	Jan 22	Feb 22	Mar 22	Apr 22	May 22	Jun 22	Jul 22	Aug 22	Sep 22	Oct 22	Nov 22	Dec 22
Tue												
Wed												
Thu												
Fri												
Sat												
Sun												

Berlin07: 450 orders, 4 years horizon



Mon	Jan 22	Feb 22	Mar 22	Apr 22	May 22	Jun 22	Jul 22	Aug 22	Sep 22	Oct 22	Nov 22	Dec 22
Tue												
Wed												
Thu												
Fri												
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Sun												

Berlin08: 559 orders, Christmas gap added

Berlin08a: 670 orders, filling gaps

Mon	Jan 22	Feb 22	Mar 22	Apr 22	May 22	Jun 22	Jul 22	Aug 22	Sep 22	Oct 22	Nov 22	Dec 22
Tue												
Wed												
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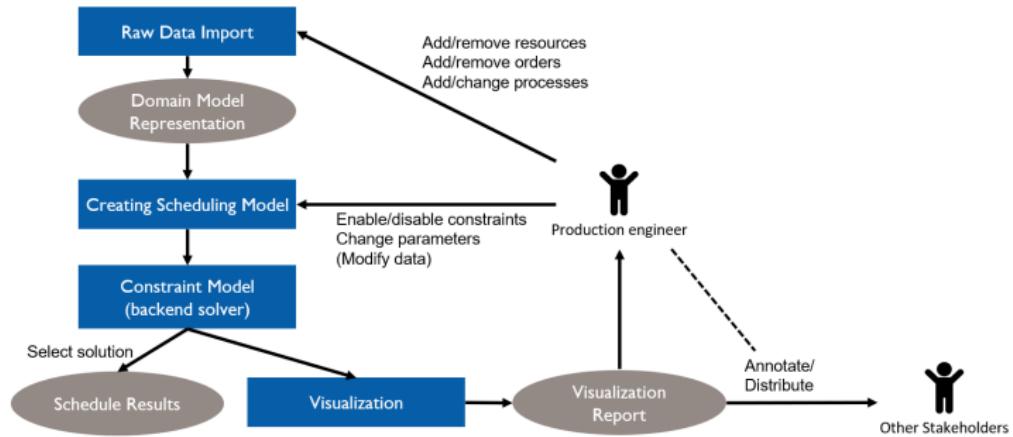
Mon	Jan 21	Feb 21	Mar 21	Apr 21	May 21	Jun 21	Jul 21	Aug 21	Sep 21	Oct 21	Nov 21	Dec 21
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# Optimizer High Level Structure



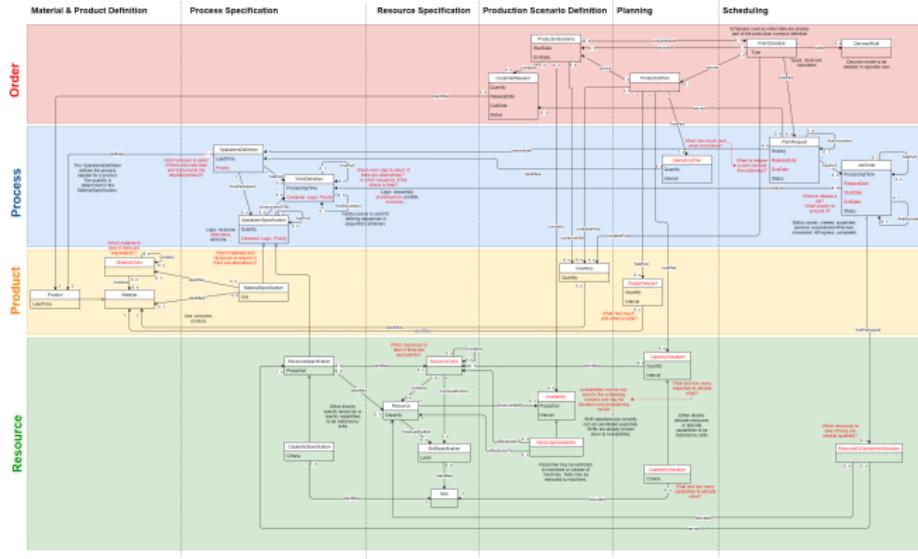
# Raw Data - Manual Data Entry Causes Problems



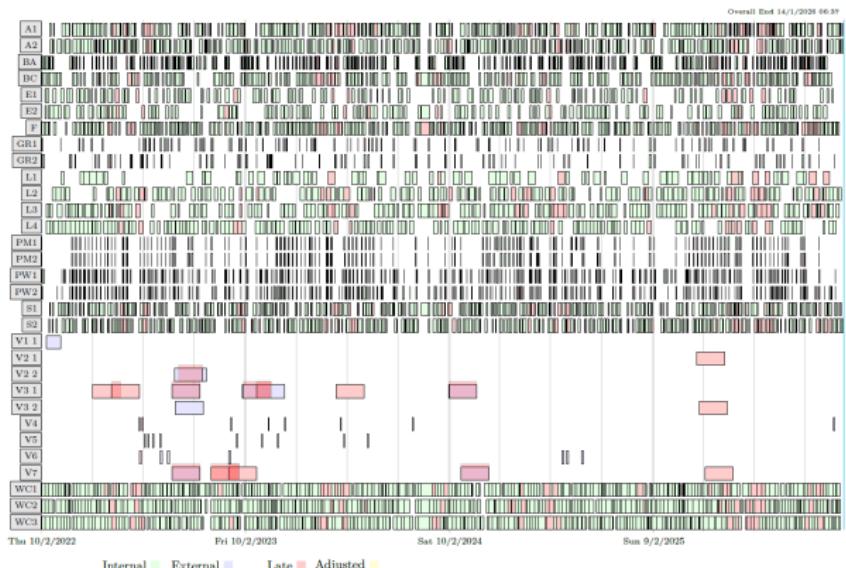
- Raw data come from spreadsheet
  - 20 tabs
- Excel is a particularly bad input data format
- Realistic, not real data
- Created by hand/automatically from existing test scenarios
- Series of files Berlin01 - Berlin05 were too inconsistent to run
- Berlin06 still contains some errors
- Optimizer explains all issues that it finds

Name	Severity	Sheet	RowNr.	ColNr.	Description
Issue1	Major	t_Load	129	11	Date/Time not formatted correctly, found 2022-02-28 00:00:00 format yyyy-mm-ddTHH:mm:ss
Issue2	Minor	t_Products	1	15	
Issue3	Minor	t_Availabilities	1	8	
Issue4	Minor	t_Uncertainties	1	8	
Issue5	Minor	t_Shift_Segments	1	6	
Issue6	Major	t_Shift_Segments	1	1	TimeOnly not formatted correctly, found 02/20000 format hh:mm:ss
Issue7	Major	t_Shift_Segments	1	2	TimeOnly not formatted correctly, found 03/20000 format hh:mm:ss
Issue8	Major	t_Shift_Segments	2	1	TimeOnly not formatted correctly, found 02/20000 format hh:mm:ss
Issue9	Major	t_Shift_Segments	2	2	TimeOnly not formatted correctly, found 04/20000 format hh:mm:ss
Issue10	Major	t_Shift_Segments	2	3	TimeOnly not formatted correctly, found 04/20000 format hh:mm:ss
Issue11	Major	t_Shift_Segments	2	4	TimeOnly not formatted correctly, found 04/20000 format hh:mm:ss
Issue12	Major	t_Shift_Segments	4	1	TimeOnly not formatted correctly, found 03/20000 format hh:mm:ss
Issue13	Major	t_Shift_Segments	4	2	TimeOnly not formatted correctly, found 03/20000 format hh:mm:ss
Issue14	Major	t_Shift_Segments	5	1	TimeOnly not formatted correctly, found 06/20000 format hh:mm:ss
Issue15	Major	t_Shift_Segments	5	2	TimeOnly not formatted correctly, found 06/20000 format hh:mm:ss
Issue16	Major	t_Shift_Segments	6	1	TimeOnly not formatted correctly, found 07/20000 format hh:mm:ss
Issue17	Major	t_Shift_Segments	6	2	TimeOnly not formatted correctly, found 07/20000 format hh:mm:ss
Issue18	Major	t_Shift_Segments	7	1	TimeOnly not formatted correctly, found 09/20000 format hh:mm:ss
Issue19	Major	t_Shift_Segments	7	2	TimeOnly not formatted correctly, found 02/20000 format hh:mm:ss
Issue20	Major	t_Shift_Segments	8	1	TimeOnly not formatted correctly, found 00/20000 format hh:mm:ss
Issue21	Major	t_Shift_Segments	8	2	TimeOnly not formatted correctly, found 07/20000 format hh:mm:ss
Issue22	Major	t_Shift_Segments	9	1	TimeOnly not formatted correctly, found 00/20000 format hh:mm:ss
Issue23	Major	t_Shift_Segments	9	2	TimeOnly not formatted correctly, found 01/20000 format hh:mm:ss
Issue24	Minor	t_Shift_Patterns	10	0	
Issue25	Minor	t_Shift_Patterns	11	0	
Issue26	Minor	t_Shift_Patterns	12	0	
Issue27	Minor	t_Shift_Patterns	13	0	
Issue28	Minor	t_Shift_Patterns	14	0	
Issue29	Minor	t_Shift_Patterns	15	0	
Issue30	Minor	t_Shift_Patterns	16	0	
Issue31	Minor	t_Shift_Patterns	17	0	
Issue32	Minor	t_Shift_Patterns	18	0	
Issue33	Minor	t_Shift_Patterns	1	9	
Issue34	Minor	t_Shift_Patterns	7	0	
Issue35	Minor	t_Shift_Patterns	8	0	

# Domain Model - Knowledge Graph



# Solution for Berlin 08a - Shows Only 20% of Tasks in Model



# Implementation

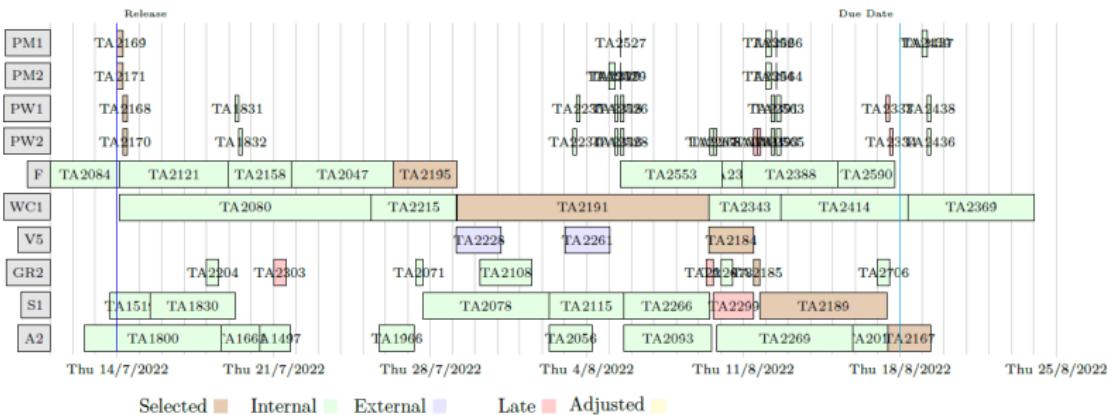


- Requirement capture done inside project
- Data checking/cleaning most time consuming aspect
- Some specified functionality was rejected by Betriebsrat
- Built in Java
- Uses IBM's CPOptimizer back-end
- 120k LoC, 110k generated, 3k solver
- Outperforms both
  - Current in-house tool
  - Simulation based tool based on commercial simulator
- System installed at SE site, but not in daily use

# Explaining Late Delivery



- Explain why some orders are delivered late
- Find root-cause, show schedule in context



# Evaluation - KPIs



KPI	Baseline	Optimizer
OTD	> 80 %	92 %
Bottleneck machine utilization	99.5 %	100 %
Manufacturing defects	10-15 %	< 10 %
Scenarios in 8 hours	15-20	> 100,000

# Conclusion by Siemens Energy



*“Within less than eight hours the ASSISTANT tools provided us thousands of manufacturing scenarios including different make-or-buy recommendations for making deliberate decisions on the way to proceed for strategic planning.”*

from ASSISTANT final project review: Siemens Energy assessment

# Summary



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