

# ASSISTANT SE Case Study

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## Constraint Based Production Scheduling



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# Acknowledgments



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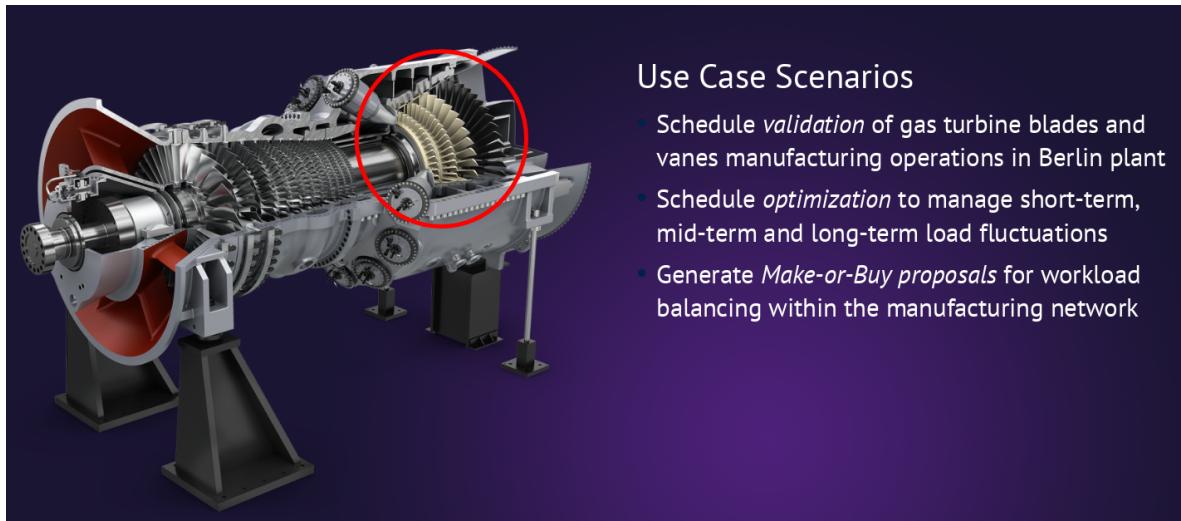
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## Key Points



- 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



## 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

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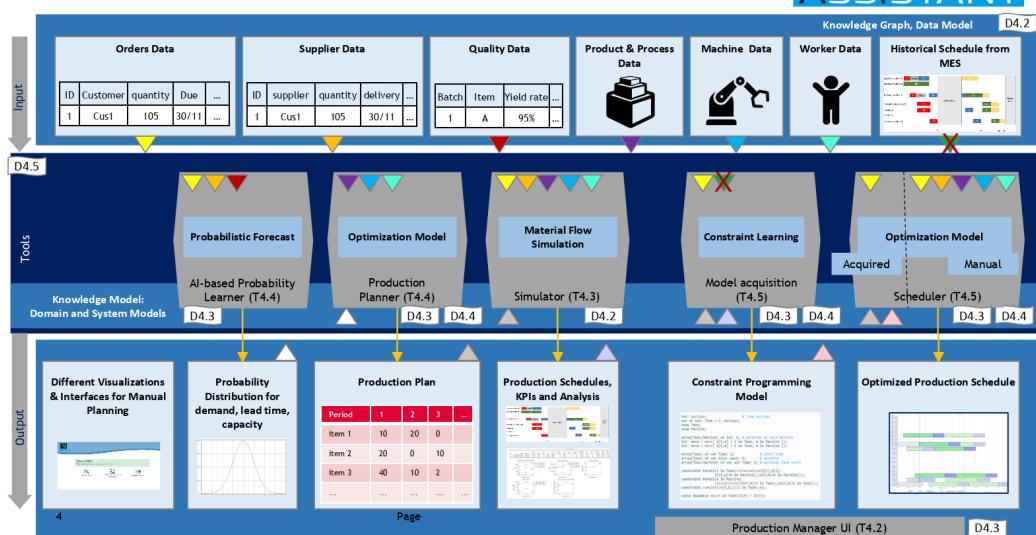
Slide 5

# ASSISTANT Project Overview



Intelligent digital twin for process planning and scheduling

ASSISTANT

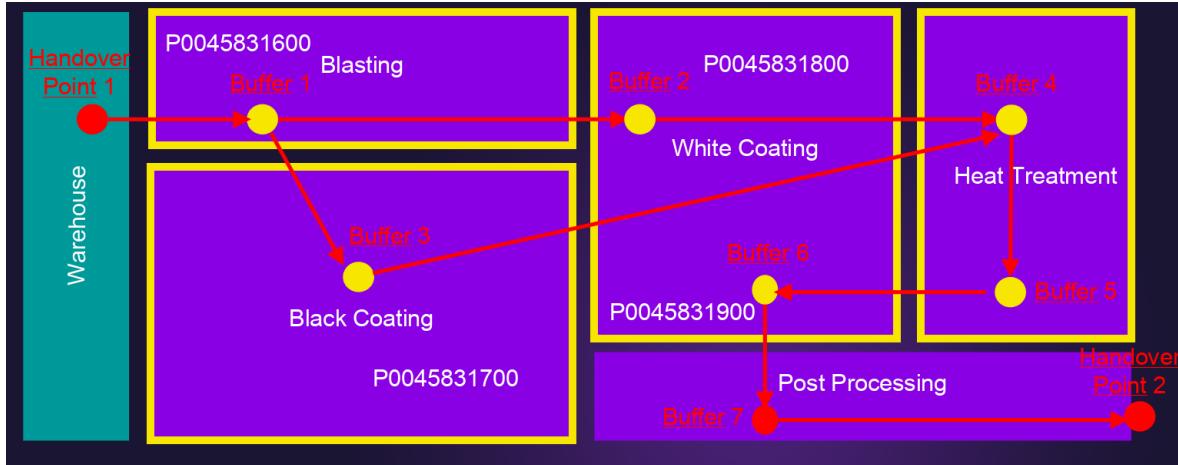


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Slide 6

# SE Product Routing



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Slide 7

## Test Datasets



### Full Scale Datasets

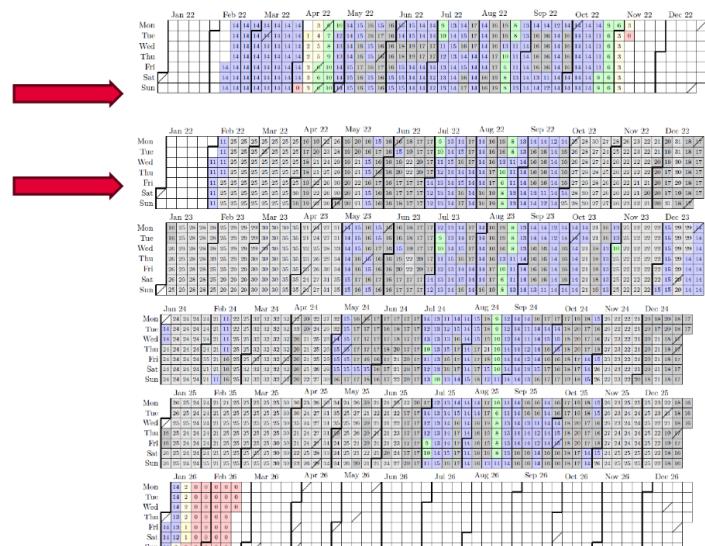
Berlin06: 96 orders, 9 months horizon, previous review

Berlin07: 450 orders, 4 years horizon

Berlin08: 559 orders, Christmas gap added

Berlin08a: 670 orders, filling gaps

Value in cell indicates active orders  
Yellow and red colors indicate low order volume

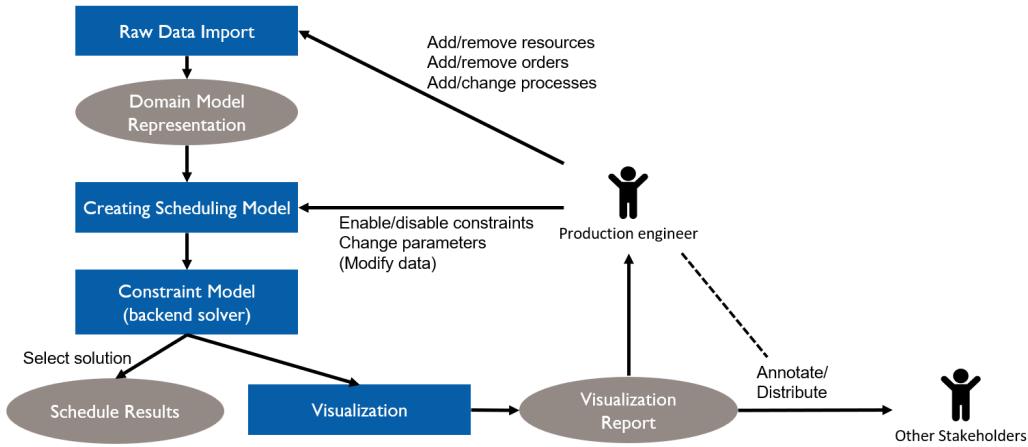


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Slide 8

# Optimizer High Level Structure



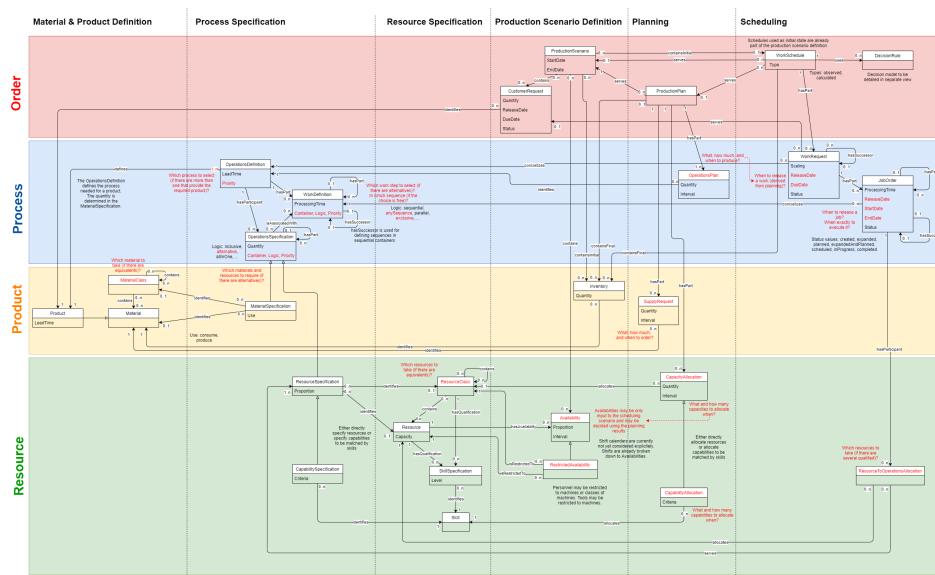
## Raw Data - Manual Data Entry Causes Problems



- 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	11	11	DateTime not formatted correctly, found 0:3997-MM-ddTHH:mm:ss
Issue2	Minor	t_Products	1	15	Extra Empty Header
Issue3	Minor	t_Availabilities	1	8	Extra Empty Header
Issue4	Minor	t_Unavailabilities	1	8	Extra Empty Header
Issue5	Minor	t_Short_Patterns	1	6	Extra Empty Header
Issue6	Major	t_Short_Segments	1	1	TimeOnly not formatted correctly, found 0.250000, format Hmmiss
Issue7	Major	t_Short_Segments	1	2	TimeOnly not formatted correctly, found 0.583333, format Hmmiss
Issue8	Major	t_Short_Segments	2	1	TimeOnly not formatted correctly, found 0.291667, format Hmmiss
Issue9	Major	t_Short_Segments	2	2	TimeOnly not formatted correctly, found 0.302083, format Hmmiss
Issue10	Major	t_Short_Segments	3	1	TimeOnly not formatted correctly, found 0.458333, format Hmmiss
Issue11	Major	t_Short_Segments	3	2	TimeOnly not formatted correctly, found 0.479167, format Hmmiss
Issue12	Major	t_Short_Segments	4	1	TimeOnly not formatted correctly, found 0.583333, format Hmmiss
Issue13	Major	t_Short_Segments	4	2	TimeOnly not formatted correctly, found 0.916667, format Hmmiss
Issue14	Major	t_Short_Segments	5	1	TimeOnly not formatted correctly, found 0.666667, format Hmmiss
Issue15	Major	t_Short_Segments	5	2	TimeOnly not formatted correctly, found 0.677083, format Hmmiss
Issue16	Major	t_Short_Segments	6	1	TimeOnly not formatted correctly, found 0.770833, format Hmmiss
Issue17	Major	t_Short_Segments	6	2	TimeOnly not formatted correctly, found 0.781667, format Hmmiss
Issue18	Major	t_Short_Segments	7	1	TimeOnly not formatted correctly, found 0.890667, format Hmmiss
Issue19	Major	t_Short_Segments	7	2	TimeOnly not formatted correctly, found 0.912500, format Hmmiss
Issue20	Major	t_Short_Segments	8	1	TimeOnly not formatted correctly, found 0.000000, format Hmmiss
Issue21	Major	t_Short_Segments	8	2	TimeOnly not formatted correctly, found 0.010417, format Hmmiss
Issue22	Major	t_Short_Segments	9	1	TimeOnly not formatted correctly, found 0.083333, format Hmmiss
Issue23	Major	t_Short_Segments	9	2	TimeOnly not formatted correctly, found 0.104167, format Hmmiss
Issue24	Minor	t_Short_Segments	10	0	First Column Empty
Issue25	Minor	t_Short_Segments	11	0	First Column Empty
Issue26	Minor	t_Short_Segments	12	0	First Column Empty
Issue27	Minor	t_Short_Segments	13	0	First Column Empty
Issue28	Minor	t_Short_Segments	14	0	First Column Empty
Issue29	Minor	t_Short_Segments	15	0	First Column Empty
Issue30	Minor	t_Short_Patterns	16	0	First Column Empty
Issue31	Minor	t_Short_Patterns	17	0	First Column Empty
Issue32	Minor	t_Short_Patterns	18	0	First Column Empty
Issue33	Minor	t_Short_Patterns	1	9	Extra Empty Header
Issue34	Minor	t_Short_Patterns	7	0	First Column Empty
Issue35	Minor	t_Short_Patterns	8	0	First Column Empty

# Domain Model - Knowledge Graph

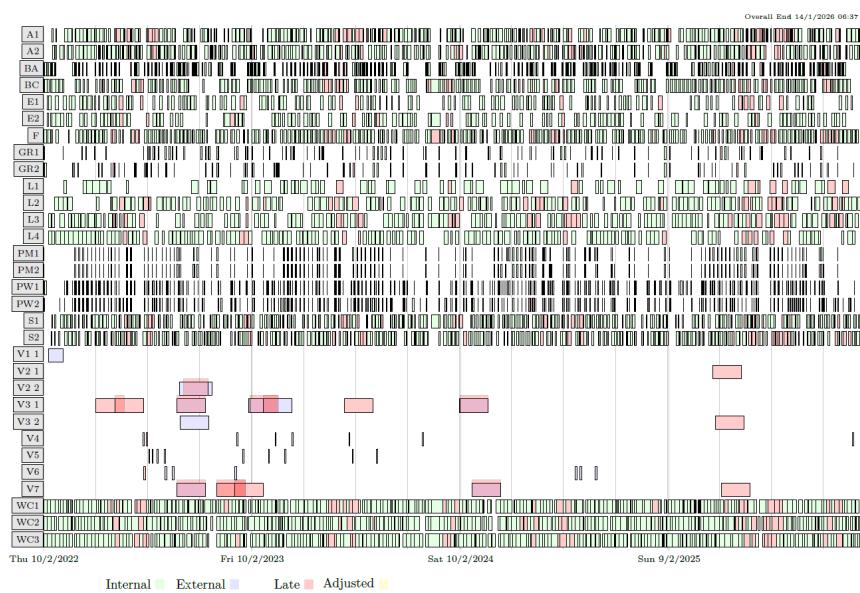


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Slide 11

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



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Slide 12

# 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

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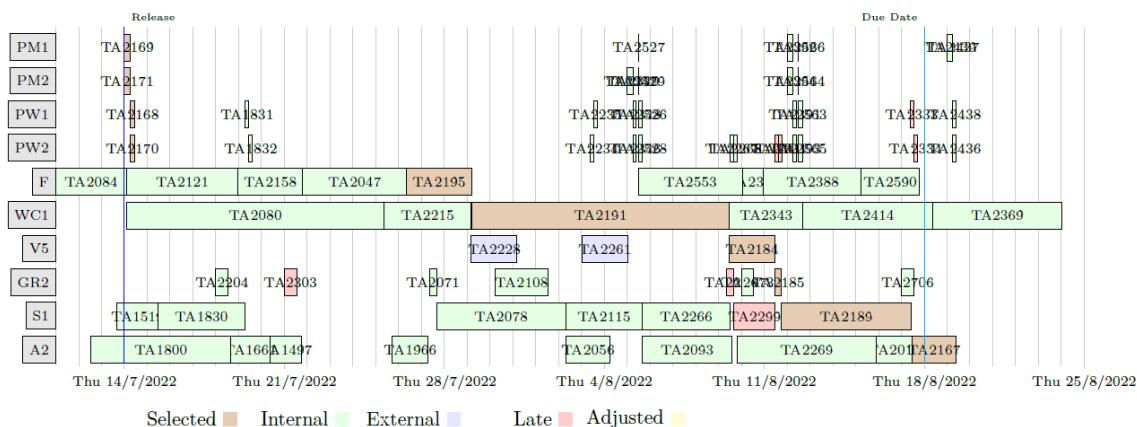
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Slide 13

## Explaining Late Delivery



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



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Slide 14

## 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

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Slide 15

## 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

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Slide 16

# Summary



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