

# ASSISTANT SE Case Study

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## Constraint Based Production Scheduling



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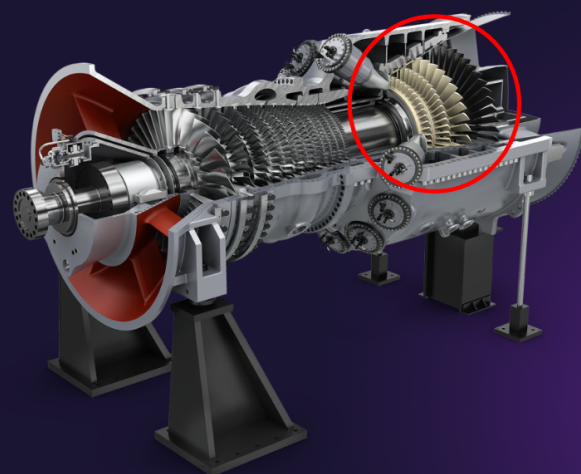
## Key Points



- 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

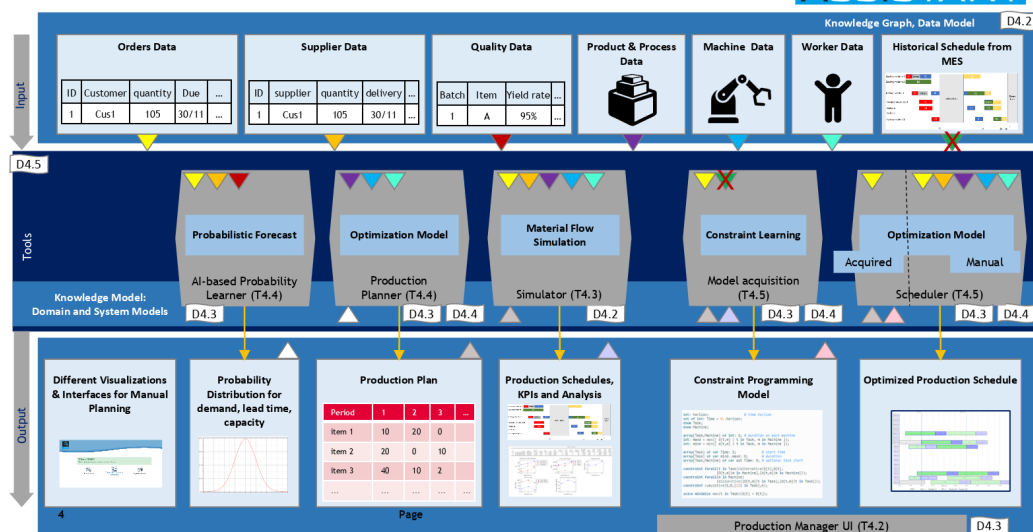
- Schedule *validation* of gas turbine blades and vanes manufacturing operations in Berlin plant
- Schedule *optimization* to manage short-term, mid-term and long-term load fluctuations
- Generate *Make-or-Buy proposals* for workload balancing within the manufacturing network

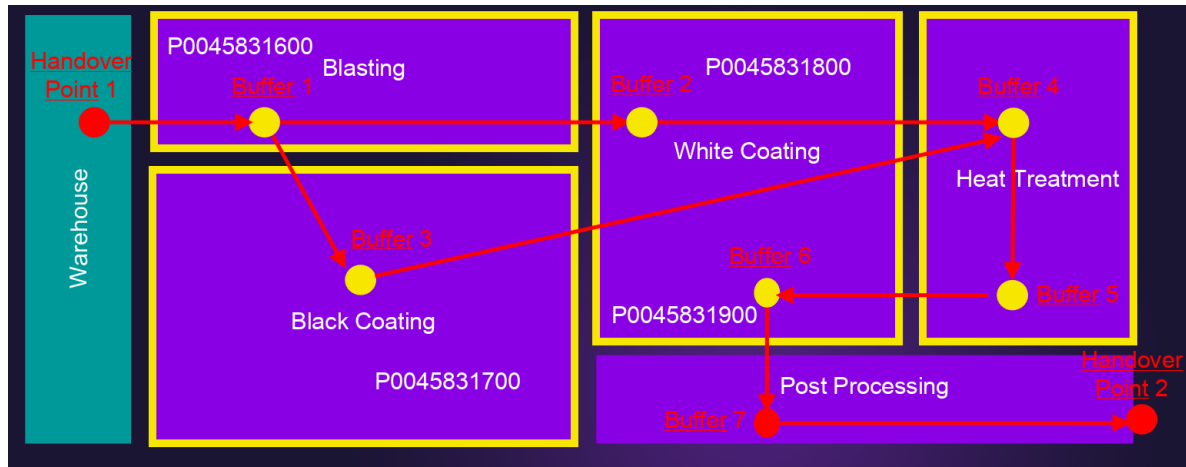
## ASSISTANT Project Overview



Intelligent digital twin for process planning and scheduling

ASSISTANT





## Test Datasets

### Full Scale Datasets

Berlin06: 96 orders, 9 months horizon, previous review

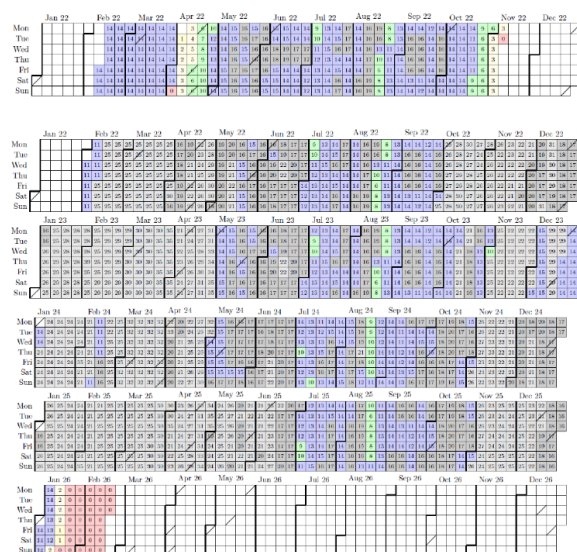
Berlin07: 450 orders, 4 years horizon

Berlin08: 559 orders, Christmas gap added

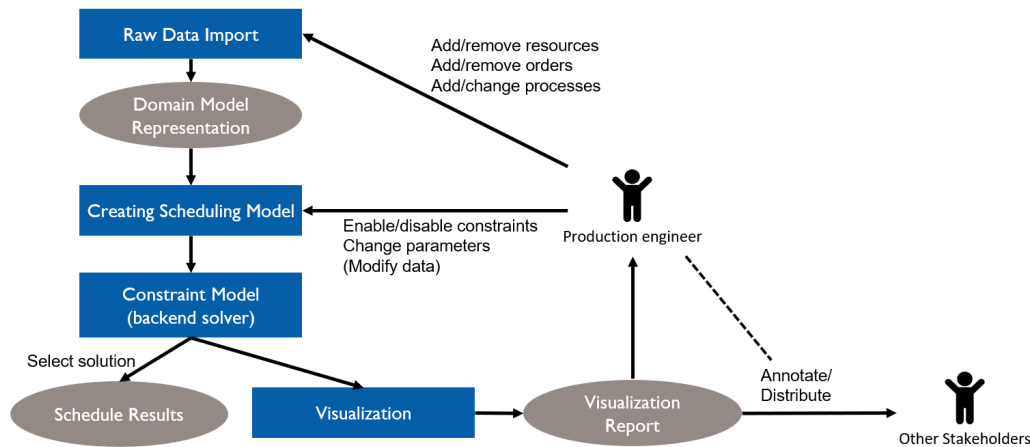
Berlin08a: 670 orders, filling gaps



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



# Optimizer High Level Structure



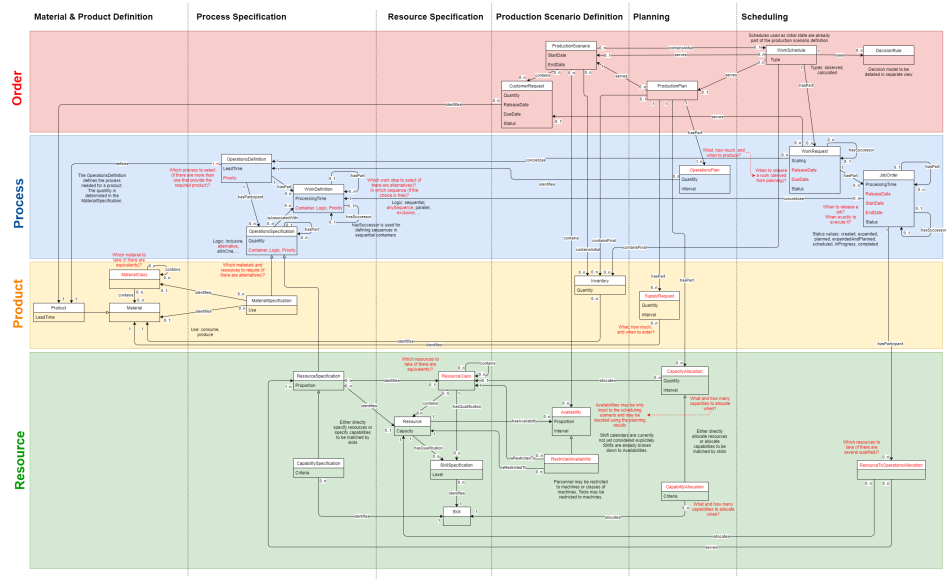
## Raw Data - Manual Data Entry Causes Problems



- 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            | RowNo | ColNo | Description                                                                           |
|---------|----------|------------------|-------|-------|---------------------------------------------------------------------------------------|
| Issue1  | Major    | t_Load           | 129   | 11    | DateTime not formatted correctly, found 2022-02-2800:00:00 format yyyy-MM-ddTTH:mm:ss |
| Issue2  | Minor    | t_Products       | 1     | 15    | Extra Empty Header                                                                    |
| Issue3  | Minor    | t_Availability   | 1     | 8     | Extra Empty Header                                                                    |
| Issue4  | Minor    | t_Unavailability | 1     | 8     | Extra Empty Header                                                                    |
| Issue5  | Minor    | t_Shift_Segments | 1     | 6     | Extra Empty Header                                                                    |
| Issue6  | Major    | t_Shift_Segments | 1     | 1     | TimeOnly not formatted correctly, found 0.250000, format H:mm:ss                      |
| Issue7  | Major    | t_Shift_Segments | 1     | 2     | TimeOnly not formatted correctly, found 0.550332, format H:mm:ss                      |
| Issue8  | Major    | t_Shift_Segments | 2     | 1     | TimeOnly not formatted correctly, found 0.291667, format H:mm:ss                      |
| Issue9  | Major    | t_Shift_Segments | 2     | 2     | TimeOnly not formatted correctly, found 0.300833, format H:mm:ss                      |
| Issue10 | Major    | t_Shift_Segments | 3     | 1     | TimeOnly not formatted correctly, found 0.458333, format H:mm:ss                      |
| Issue11 | Major    | t_Shift_Segments | 3     | 2     | TimeOnly not formatted correctly, found 0.479167, format H:mm:ss                      |
| Issue12 | Major    | t_Shift_Segments | 4     | 1     | TimeOnly not formatted correctly, found 0.563333, format H:mm:ss                      |
| Issue13 | Major    | t_Shift_Segments | 4     | 2     | TimeOnly not formatted correctly, found 0.916667, format H:mm:ss                      |
| Issue14 | Major    | t_Shift_Segments | 5     | 1     | TimeOnly not formatted correctly, found 0.866667, format H:mm:ss                      |
| Issue15 | Major    | t_Shift_Segments | 5     | 2     | TimeOnly not formatted correctly, found 0.677083, format H:mm:ss                      |
| Issue16 | Major    | t_Shift_Segments | 6     | 1     | TimeOnly not formatted correctly, found 0.770833, format H:mm:ss                      |
| Issue17 | Major    | t_Shift_Segments | 6     | 2     | TimeOnly not formatted correctly, found 0.791667, format H:mm:ss                      |
| Issue18 | Major    | t_Shift_Segments | 7     | 1     | TimeOnly not formatted correctly, found 0.916667, format H:mm:ss                      |
| Issue19 | Major    | t_Shift_Segments | 7     | 2     | TimeOnly not formatted correctly, found 0.250000, format H:mm:ss                      |
| Issue20 | Major    | t_Shift_Segments | 8     | 1     | TimeOnly not formatted correctly, found 0.000000, format H:mm:ss                      |
| Issue21 | Major    | t_Shift_Segments | 8     | 2     | TimeOnly not formatted correctly, found 0.010417, format H:mm:ss                      |
| Issue22 | Major    | t_Shift_Segments | 9     | 1     | TimeOnly not formatted correctly, found 0.083333, format H:mm:ss                      |
| Issue23 | Major    | t_Shift_Segments | 9     | 2     | TimeOnly not formatted correctly, found 0.104167, format H:mm:ss                      |
| Issue24 | Minor    | t_Shift_Segments | 10    | 0     | First Column Empty                                                                    |
| Issue25 | Minor    | t_Shift_Segments | 11    | 0     | First Column Empty                                                                    |
| Issue26 | Minor    | t_Shift_Segments | 12    | 0     | First Column Empty                                                                    |
| Issue27 | Minor    | t_Shift_Segments | 13    | 0     | First Column Empty                                                                    |
| Issue28 | Minor    | t_Shift_Segments | 14    | 0     | First Column Empty                                                                    |
| Issue29 | Minor    | t_Shift_Segments | 15    | 0     | First Column Empty                                                                    |
| Issue30 | Minor    | t_Shift_Segments | 16    | 0     | First Column Empty                                                                    |
| Issue31 | Minor    | t_Shift_Segments | 17    | 0     | First Column Empty                                                                    |
| Issue32 | Minor    | t_Shift_Segments | 18    | 0     | First Column Empty                                                                    |
| Issue33 | Minor    | t_Shift_Patterns | 1     | 9     | Extra Empty Header                                                                    |
| Issue34 | Minor    | t_Shift_Patterns | 7     | 0     | First Column Empty                                                                    |
| Issue35 | Minor    | t_Shift_Patterns | 8     | 0     | First Column Empty                                                                    |

# Domain Model - Knowledge Graph



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

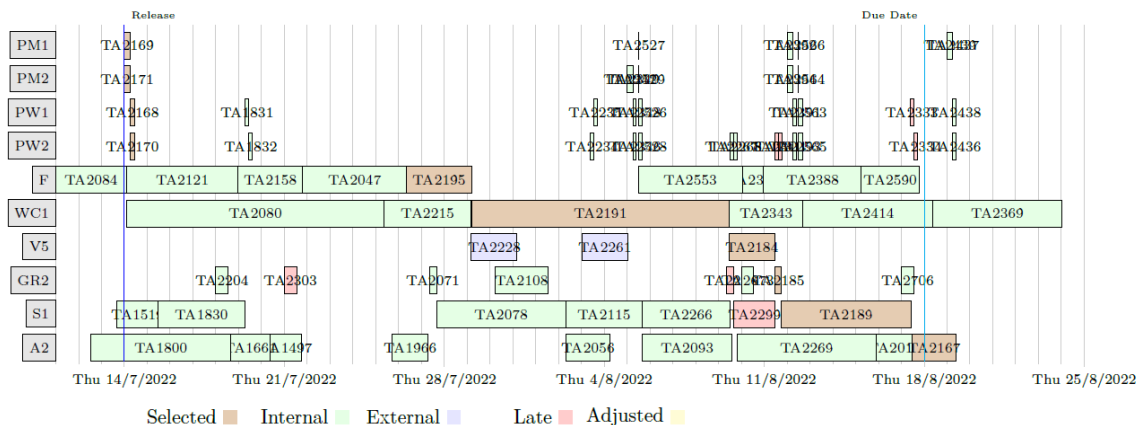


- Requirement capture done inside project
- Data checking/cleaning most time consuming aspect
- Some specified functionality was rejected by Betriebsrat
- Built in Java
- Uses IBM's CPOptimizer back-end
- 120k LoC, 110k generated, 3k solver
- Outperforms both
  - Current in-house tool
  - Simulation 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





| 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





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