

# ASSISTANT SE Case Study

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## Constraint Based Production Scheduling

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# Acknowledgments



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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

# Insight is one of the largest data research and innovation centres in Europe...



Ollscoil na Gaillimhe  
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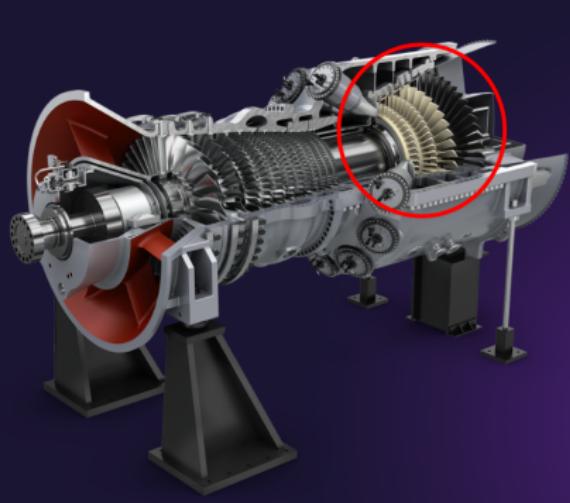


Trinity College Dublin  
Coláiste an TríBeoile, Baile Átha Cliath  
The University of Dublin



<b>4</b> Co-Lead Universities 9 partner institutions	Built on <b>20</b> years of research in Data Analytics and AI
<b>450+</b> Academics, Postdocs, PhDs, RAs	<b>3400+</b> Scientific conference and journal papers
<b>175+</b> Funded collaborations with industry partners	<b>350+</b> Research Awards
<b>16</b> Spin out companies 72 license agreements	<b>135+</b> H2020 consortia, 500+ collaborations, 40+ countries
<b>1,137+</b> school visits, 28,000 students	<b>276</b> PhDs graduated

# Assistant Siemens Energy Use Case



The image shows a detailed cross-section of a gas turbine engine. A red circle highlights the compressor section, which is the first stage of the engine where air is compressed before entering the combustion chamber. The engine features a multi-stage compressor with various blades and a complex internal structure of shafts and bearings.

### Use Case Scenarios

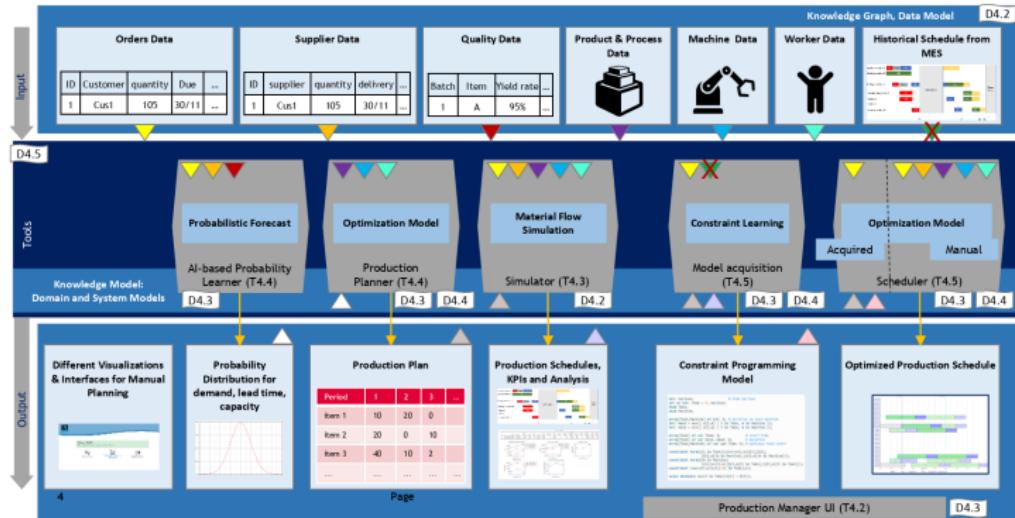
- Schedule *validation* of gas turbine blades and vanes manufacturing operations in Berlin plant
- Schedule *optimization* to manage short-term, mid-term and long-term load fluctuations
- Generate *Make-or-Buy proposals* for workload balancing within the manufacturing network

# ASSISTANT Project Overview

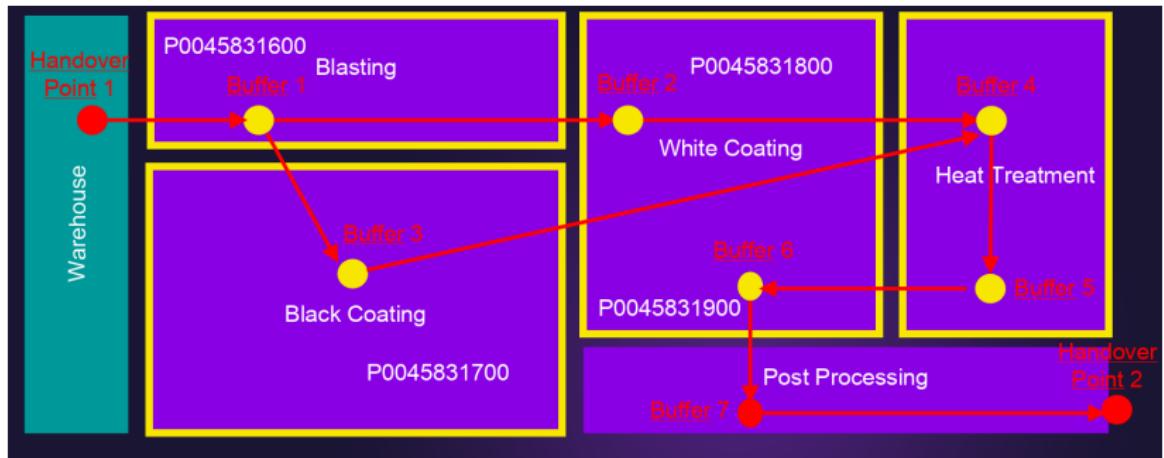


Intelligent digital twin for process planning and scheduling

ASSISTANT



# SE Product Routing



# Test Datasets



## Full Scale Datasets

Berlin06: 96 orders, 9 months horizon, previous review

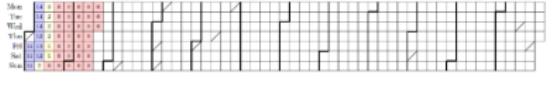
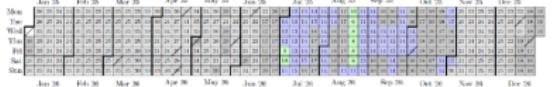
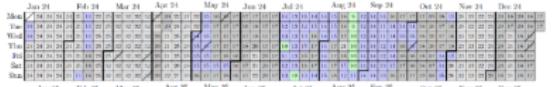
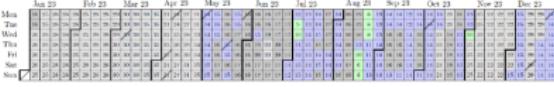


Berlin07: 450 orders, 4 years horizon



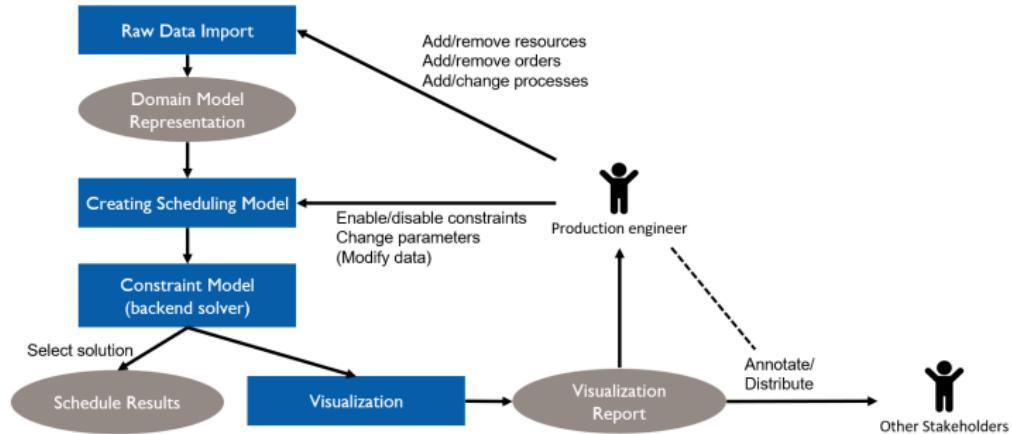
Berlin08: 559 orders, Christmas gap added

Berlin08a: 670 orders, filling gaps



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

# Optimizer High Level Structure



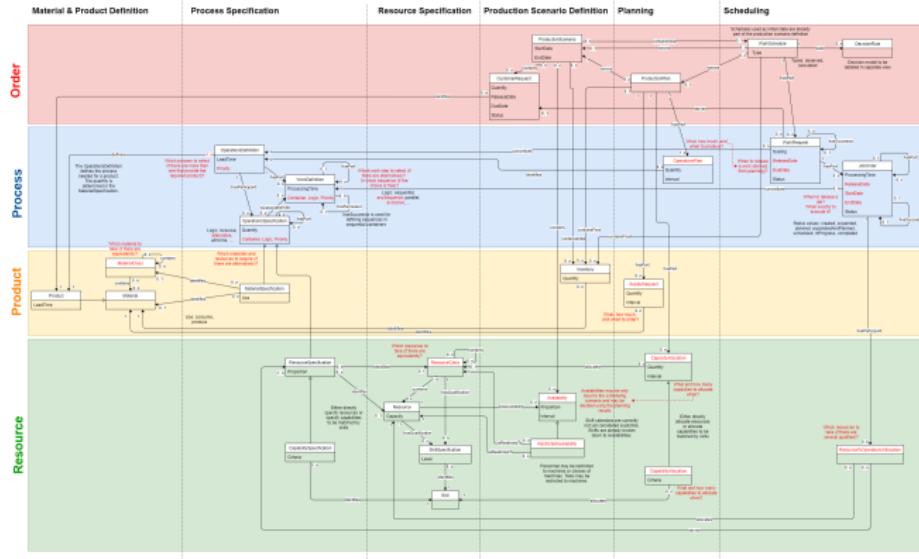
# Raw Data - Manual Data Entry Causes Problems



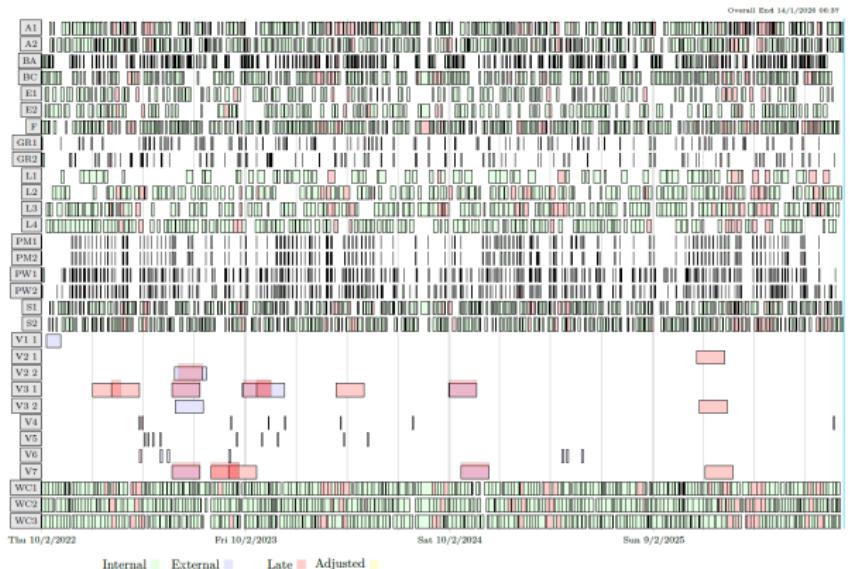
- Raw data come from spreadsheet
  - 20 tabs
- Excel is a particularly bad input data format
- Realistic, not real data
- Created by hand/automatically from existing test scenarios
- Series of files Berlin01 - Berlin05 were too inconsistent to run
- Berlin06 still contains some errors
- Optimizer explains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

Issue #	Name	Severity	Sheet	Row#	Col#	Description
Issue1	Minor	Low	U_Products	1	11	Date/Time not formatted correctly, found 2022-02-28000000 format yyyy-MM-dd'T'HHmmss
Issue2	Minor	Low	U_Products	1	15	Extra Empty Header
Issue3	Minor	Low	U_Availability	1	8	Extra Empty Header
Issue4	Minor	Low	U_Availability	1	9	Extra Empty Header
Issue5	Minor	Low	U_Shift_Segments	1	6	Extra Empty Header
Issue6	Major	High	U_Shift_Segments	1	1	TimeOnly not formatted correctly, found 02:0000, format hh:mm:ss
Issue7	Major	High	U_Shift_Segments	1	2	TimeOnly not formatted correctly, found 03:0033, format hh:mm:ss
Issue8	Major	High	U_Shift_Segments	2	1	TimeOnly not formatted correctly, found 02:0007, format hh:mm:ss
Issue9	Major	High	U_Shift_Segments	2	2	TimeOnly not formatted correctly, found 03:0003, format hh:mm:ss
Issue10	Major	High	U_Shift_Segments	3	1	TimeOnly not formatted correctly, found 04:0033, format hh:mm:ss
Issue11	Major	High	U_Shift_Segments	3	2	TimeOnly not formatted correctly, found 04:0007, format hh:mm:ss
Issue12	Major	High	U_Shift_Segments	4	1	TimeOnly not formatted correctly, found 03:0033, format hh:mm:ss
Issue13	Major	High	U_Shift_Segments	4	2	TimeOnly not formatted correctly, found 03:0007, format hh:mm:ss
Issue14	Major	High	U_Shift_Segments	5	1	TimeOnly not formatted correctly, found 04:0007, format hh:mm:ss
Issue15	Major	High	U_Shift_Segments	5	2	TimeOnly not formatted correctly, found 03:0003, format hh:mm:ss
Issue16	Major	High	U_Shift_Segments	6	1	TimeOnly not formatted correctly, found 03:0003, format hh:mm:ss
Issue17	Major	High	U_Shift_Segments	6	2	TimeOnly not formatted correctly, found 03:0007, format hh:mm:ss
Issue18	Major	High	U_Shift_Segments	7	1	TimeOnly not formatted correctly, found 03:0003, format hh:mm:ss
Issue19	Major	High	U_Shift_Segments	7	2	TimeOnly not formatted correctly, found 03:0000, format hh:mm:ss
Issue20	Minor	Low	U_Shift_Segments	8	1	TimeOnly not formatted correctly, found 03:0000, format hh:mm:ss
Issue21	Minor	Low	U_Shift_Segments	8	2	TimeOnly not formatted correctly, found 03:0007, format hh:mm:ss
Issue22	Minor	Low	U_Shift_Segments	9	1	TimeOnly not formatted correctly, found 03:0033, format hh:mm:ss
Issue23	Minor	Low	U_Shift_Segments	9	2	TimeOnly not formatted correctly, found 03:0007, format hh:mm:ss
Issue24	Minor	Low	U_Shift_Segments	10	0	First Column Empty
Issue25	Minor	Low	U_Shift_Segments	11	0	First Column Empty
Issue26	Minor	Low	U_Shift_Segments	12	0	First Column Empty
Issue27	Minor	Low	U_Shift_Segments	13	0	First Column Empty
Issue28	Minor	Low	U_Shift_Segments	14	0	First Column Empty
Issue29	Minor	Low	U_Shift_Segments	15	0	First Column Empty
Issue30	Minor	Low	U_Shift_Segments	16	0	First Column Empty
Issue31	Minor	Low	U_Shift_Segments	17	0	First Column Empty
Issue32	Minor	Low	U_Shift_Segments	18	0	First Column Empty
Issue33	Minor	Low	U_Shift_Patterns	1	9	Extra Empty Header
Issue34	Minor	Low	U_Shift_Patterns	7	0	First Column Empty
Issue35	Minor	Low	U_Shift_Patterns	8	0	First Column Empty

# Domain Model - Knowledge Graph



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



# Implementation

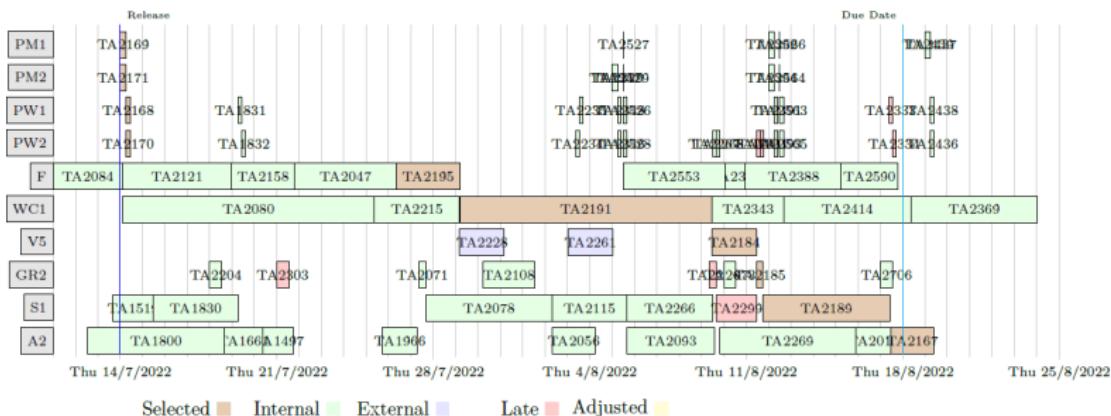


- Requirement capture done inside project
- Data checking/cleaning most time consuming aspect
- Some specified functionality was rejected by Betriebsrat
- Built in Java
- Uses IBM's CPOptimizer back-end
- 120k LoC, 110k generated, 3k solver
- Outperforms both
  - Current in-house tool
  - Simulation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