



Add value.  
Inspire trust.

## HAZOP+

Your path to a safe and  
optimized plant

Dordrecht Conf. - 01.10.2021

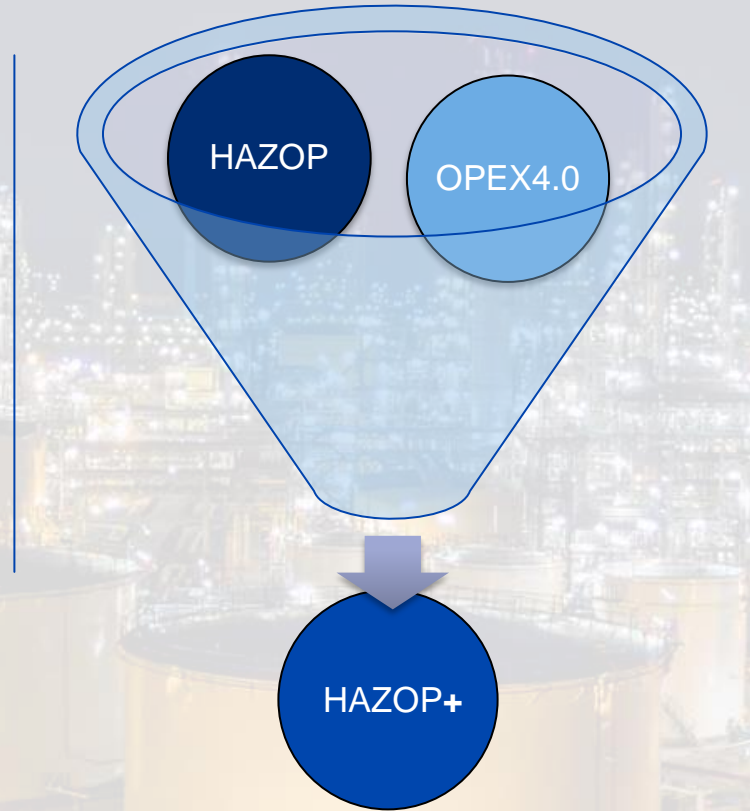
Dr. Hans Volkmar Schwarz  
Kurt Verheyden



# HAZOP + OPEX4.0 = HAZOP+

## ■ HAZOP

- Analysis method of process safety
- Results: determination of risks and eventually defining the corresponding risk reducing measures
- Deep and highly resource intensive analysis, through which a plant is put after its original design process



## ■ OPEX4.0

- Many companies have a systematic OPEX (Operational Excellence) process, which is used to optimize yields, utility usage, minimize unplanned downtime, and other parameters with an impact on costs.
- The optimization of operating parameters is optimally based on data centered methods, and AI for the Interpretation of the operating data.

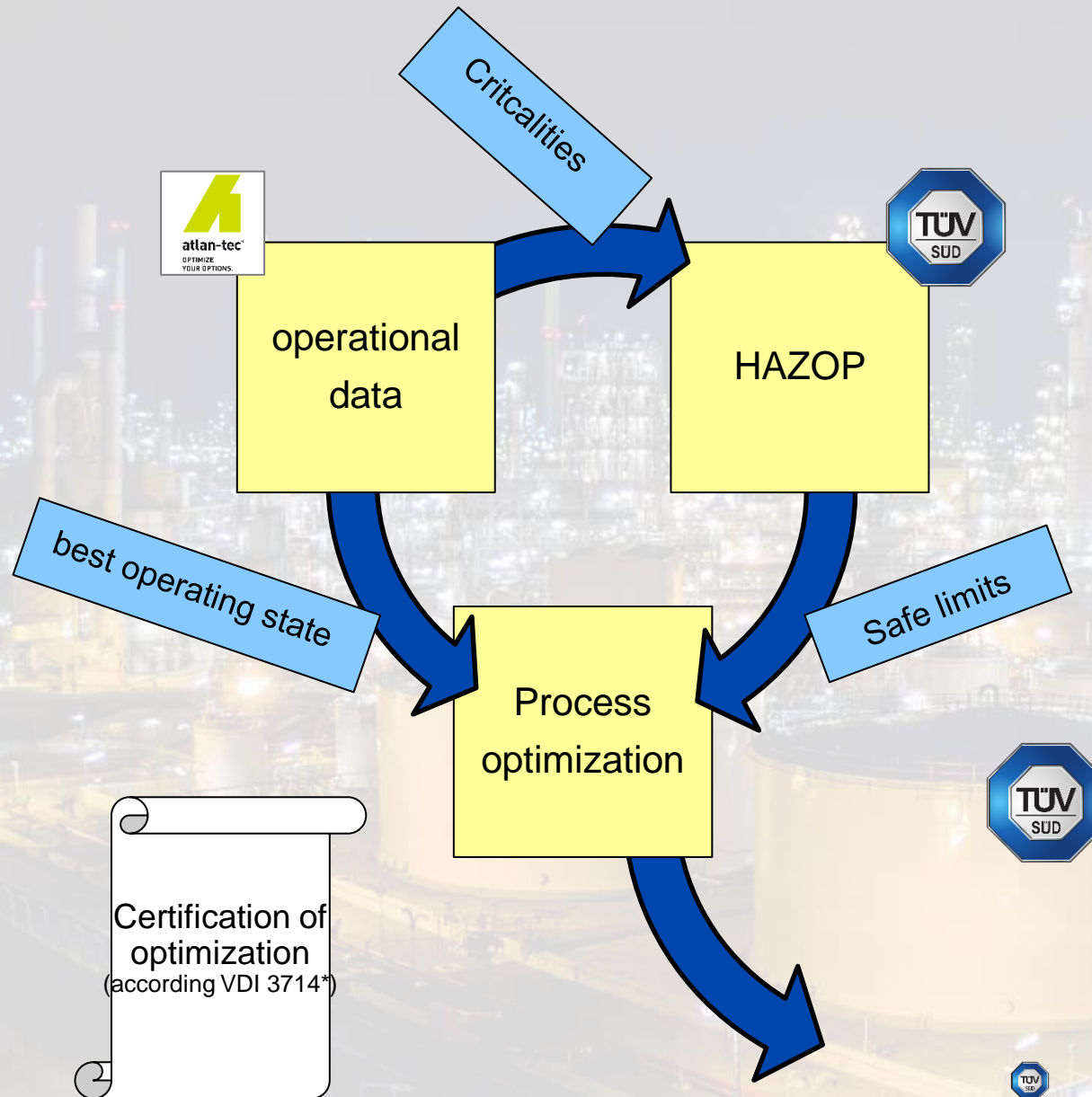
## ■ HAZOP+

- is the combination of a HAZOP study with an OPEX4.0 project, realizing synergies between the two

# HAZOP+ workflow

- HAZOP study performed by experienced TUV SUD experts
- OPEX4.0 performed by contract partner atlan-tec systems (ats)
- Combination of process safety review (HAZOP) and operational optimization (OPEX 4.0)
- Optimization of operating parameters using Machine Learning
- Certification of optimization according VDI 3714\*

\*VDI3714: German engineering guideline for the optimal execution of big data projects





# Execution of HAZOP+ Projects

## Preparation

- Needed documents
- Updates needed ?
- Data (from DCS, Lab..)

- P&ID, Control scheme, plot plan, equipment data,...
- Plant upsets, repairs, incidents, ...
- Operating parameter data from DCS, LIMS, ideally from several years
- Simulation results (if available)

## Analysis

- HAZOP study
- Data- & AI- based analysis of operation

- OPEX4.0:
  - Analysis and formation of models.
  - Determining good and bad run periods
- HAZOP: Review of all P&IDs, Check of all safety devices (SIL, PSVs,...)
- Synergies:
  - Limits of optimisation
  - Including plant upsets and bad run periods in the HAZOP study

## Implementation

- HAZOP action items
- Optimisations

- Optimized setpoints of relevant control loops
  - Offline, Operator input
  - Closed loop: AI feeds optimized setpoints directly to DCS
- Safety measures resulting from HAZOP
- Certification of the Optimization according VDI3714 through TÜV SÜD

## Follow up, Finetuning

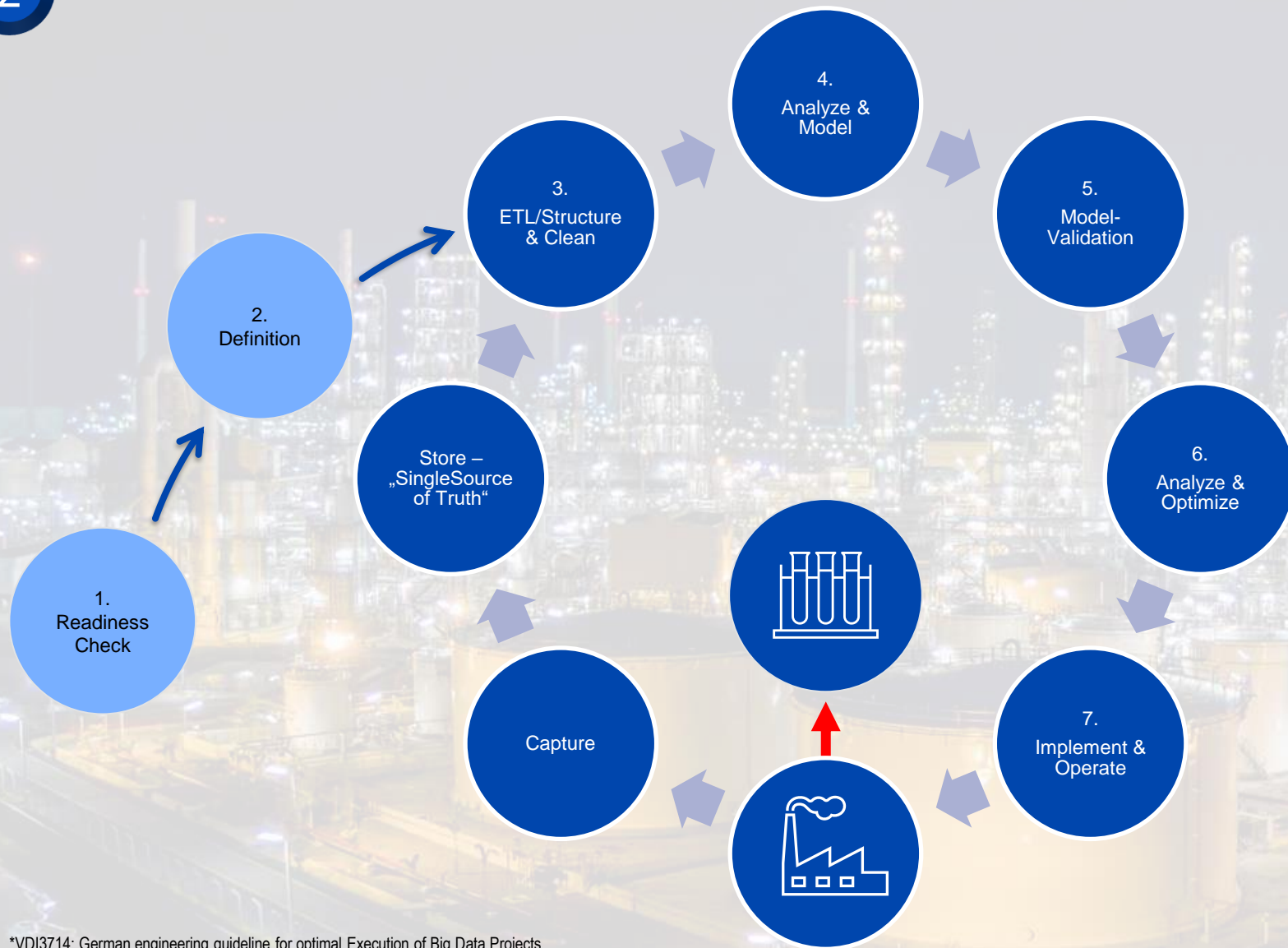
- Follow up on HAZOP measures/action items
- Further optimization of operating parameters with statistical models of the AI

# Preparation of Documents and Data

- Both studies benefit from efficient and target oriented document preparation
- For both studies updated design documents and operating data are needed (e.g. P&IDs, control schemes, time sequence/trends of process parameters, List of undesired events, etc).
  - Synergy in the preparation of data and documents regarding time & effort
  - Good preparation leads to efficient execution and reduced costs of both studies
- An assessment of 'Industry 4.0 Readiness' can be useful in the preparation phase:
  - SIRI assessment of TÜV SÜD (online or offline)
  - Industry 4.0 readiness assessment of ats (online)







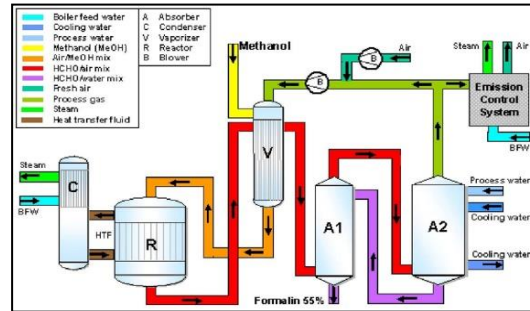
\*VDI3714: German engineering guideline for optimal Execution of Big Data Projects  
 DCS = Distr. Control System  
 LIMS = Laboratory Information Management System

# Analysis, OPEX4.0

- Optimization of operating parameters using AI / Machine Learning
- Operating data from the DCS\* and LIMS\* are filtered regarding relevance for the optimization
- Operating data are processed into statistical models, which identify optimal operating parameters
- models are tested and further optimized - Optimizer software uses the models to maximize target functions such as EBIT/hr
- The new setpoints are fed manually or automatically to the DCS, in order to control the the plant as close as possible at the optimal operating conditions
- The Optimization follows the steps of Guideline VDI3714\*
- Plan for 2021: Certification through TÜV SÜD

# Optimization of operating parameters using Machine Learning

Constructing a statistical model, which connects Process Variables with costs/ton



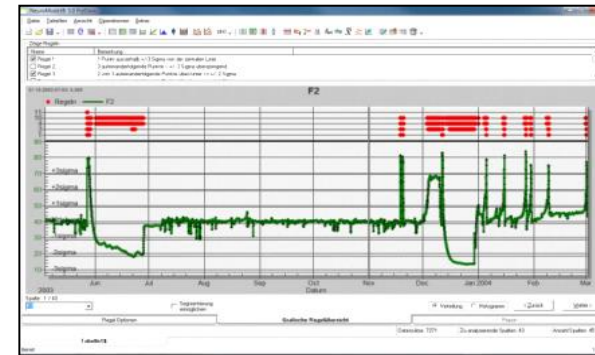
**HISTORICAL DATA**

Time	Temp	Pressure	Flow	Cost	...
2000-01-01 00:00:00	100.0	1.0	1.0	1.0	...
2000-01-01 00:01:00	100.1	1.0	1.0	1.0	...
2000-01-01 00:02:00	100.2	1.0	1.0	1.0	...
2000-01-01 00:03:00	100.3	1.0	1.0	1.0	...
2000-01-01 00:04:00	100.4	1.0	1.0	1.0	...
2000-01-01 00:05:00	100.5	1.0	1.0	1.0	...
2000-01-01 00:06:00	100.6	1.0	1.0	1.0	...
2000-01-01 00:07:00	100.7	1.0	1.0	1.0	...
2000-01-01 00:08:00	100.8	1.0	1.0	1.0	...
2000-01-01 00:09:00	100.9	1.0	1.0	1.0	...
2000-01-01 00:10:00	101.0	1.0	1.0	1.0	...
2000-01-01 00:11:00	101.1	1.0	1.0	1.0	...
2000-01-01 00:12:00	101.2	1.0	1.0	1.0	...
2000-01-01 00:13:00	101.3	1.0	1.0	1.0	...
2000-01-01 00:14:00	101.4	1.0	1.0	1.0	...
2000-01-01 00:15:00	101.5	1.0	1.0	1.0	...
2000-01-01 00:16:00	101.6	1.0	1.0	1.0	...
2000-01-01 00:17:00	101.7	1.0	1.0	1.0	...
2000-01-01 00:18:00	101.8	1.0	1.0	1.0	...
2000-01-01 00:19:00	101.9	1.0	1.0	1.0	...
2000-01-01 00:20:00	102.0	1.0	1.0	1.0	...
2000-01-01 00:21:00	102.1	1.0	1.0	1.0	...
2000-01-01 00:22:00	102.2	1.0	1.0	1.0	...
2000-01-01 00:23:00	102.3	1.0	1.0	1.0	...
2000-01-01 00:24:00	102.4	1.0	1.0	1.0	...
2000-01-01 00:25:00	102.5	1.0	1.0	1.0	...
2000-01-01 00:26:00	102.6	1.0	1.0	1.0	...
2000-01-01 00:27:00	102.7	1.0	1.0	1.0	...
2000-01-01 00:28:00	102.8	1.0	1.0	1.0	...
2000-01-01 00:29:00	102.9	1.0	1.0	1.0	...
2000-01-01 00:30:00	103.0	1.0	1.0	1.0	...
2000-01-01 00:31:00	103.1	1.0	1.0	1.0	...
2000-01-01 00:32:00	103.2	1.0	1.0	1.0	...
2000-01-01 00:33:00	103.3	1.0	1.0	1.0	...
2000-01-01 00:34:00	103.4	1.0	1.0	1.0	...
2000-01-01 00:35:00	103.5	1.0	1.0	1.0	...
2000-01-01 00:36:00	103.6	1.0	1.0	1.0	...
2000-01-01 00:37:00	103.7	1.0	1.0	1.0	...
2000-01-01 00:38:00	103.8	1.0	1.0	1.0	...
2000-01-01 00:39:00	103.9	1.0	1.0	1.0	...
2000-01-01 00:40:00	104.0	1.0	1.0	1.0	...
2000-01-01 00:41:00	104.1	1.0	1.0	1.0	...
2000-01-01 00:42:00	104.2	1.0	1.0	1.0	...
2000-01-01 00:43:00	104.3	1.0	1.0	1.0	...
2000-01-01 00:44:00	104.4	1.0	1.0	1.0	...
2000-01-01 00:45:00	104.5	1.0	1.0	1.0	...
2000-01-01 00:46:00	104.6	1.0	1.0	1.0	...
2000-01-01 00:47:00	104.7	1.0	1.0	1.0	...
2000-01-01 00:48:00	104.8	1.0	1.0	1.0	...
2000-01-01 00:49:00	104.9	1.0	1.0	1.0	...
2000-01-01 00:50:00	105.0	1.0	1.0	1.0	...
2000-01-01 00:51:00	105.1	1.0	1.0	1.0	...
2000-01-01 00:52:00	105.2	1.0	1.0	1.0	...
2000-01-01 00:53:00	105.3	1.0	1.0	1.0	...
2000-01-01 00:54:00	105.4	1.0	1.0	1.0	...
2000-01-01 00:55:00	105.5	1.0	1.0	1.0	...
2000-01-01 00:56:00	105.6	1.0	1.0	1.0	...
2000-01-01 00:57:00	105.7	1.0	1.0	1.0	...
2000-01-01 00:58:00	105.8	1.0	1.0	1.0	...
2000-01-01 00:59:00	105.9	1.0	1.0	1.0	...
2000-01-01 01:00:00	106.0	1.0	1.0	1.0	...

\$/t

Model

FIC3221  
LIC245  
TIC1207  
FIC1284  
AI2234  
AI2945  
PC285  
PC248  
TIC1356  
.....

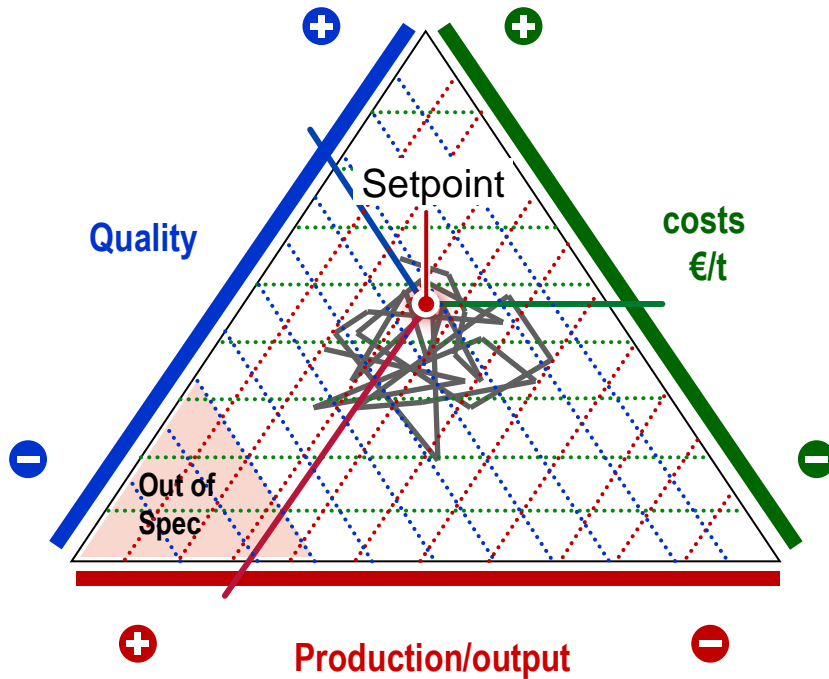


Advanced Analytics /  
NeuroModel®

# Optimization of operating parameters using Machine Learning

From traditional process control with fluctuations / suboptimal performance...

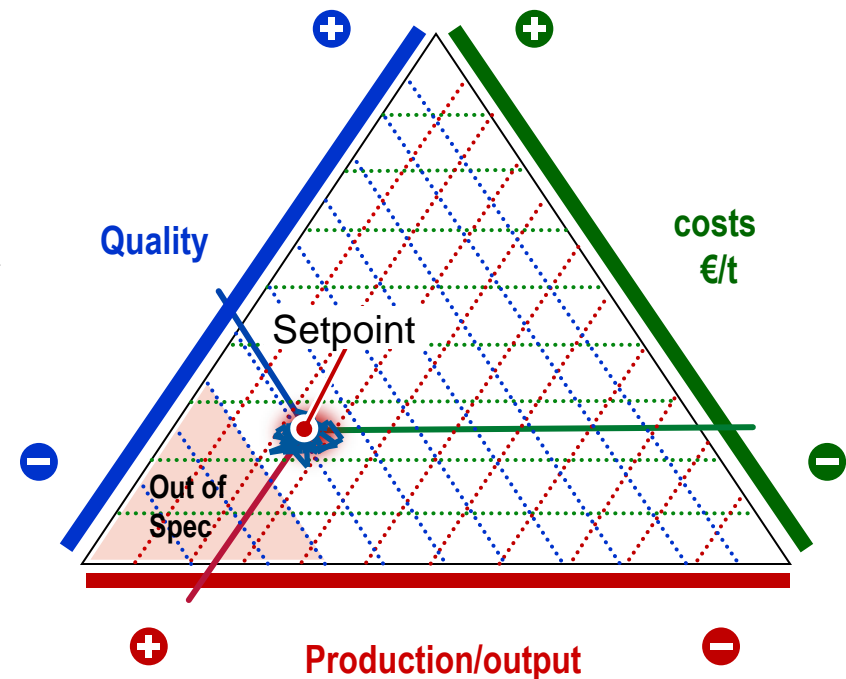
higher variability of important process parameters requires wider safety margins relative to optimal conditions



ML based  
Optimization +  
HAZOP

... to optimized operation according APC 4.0 with minimized costs / higher efficiency

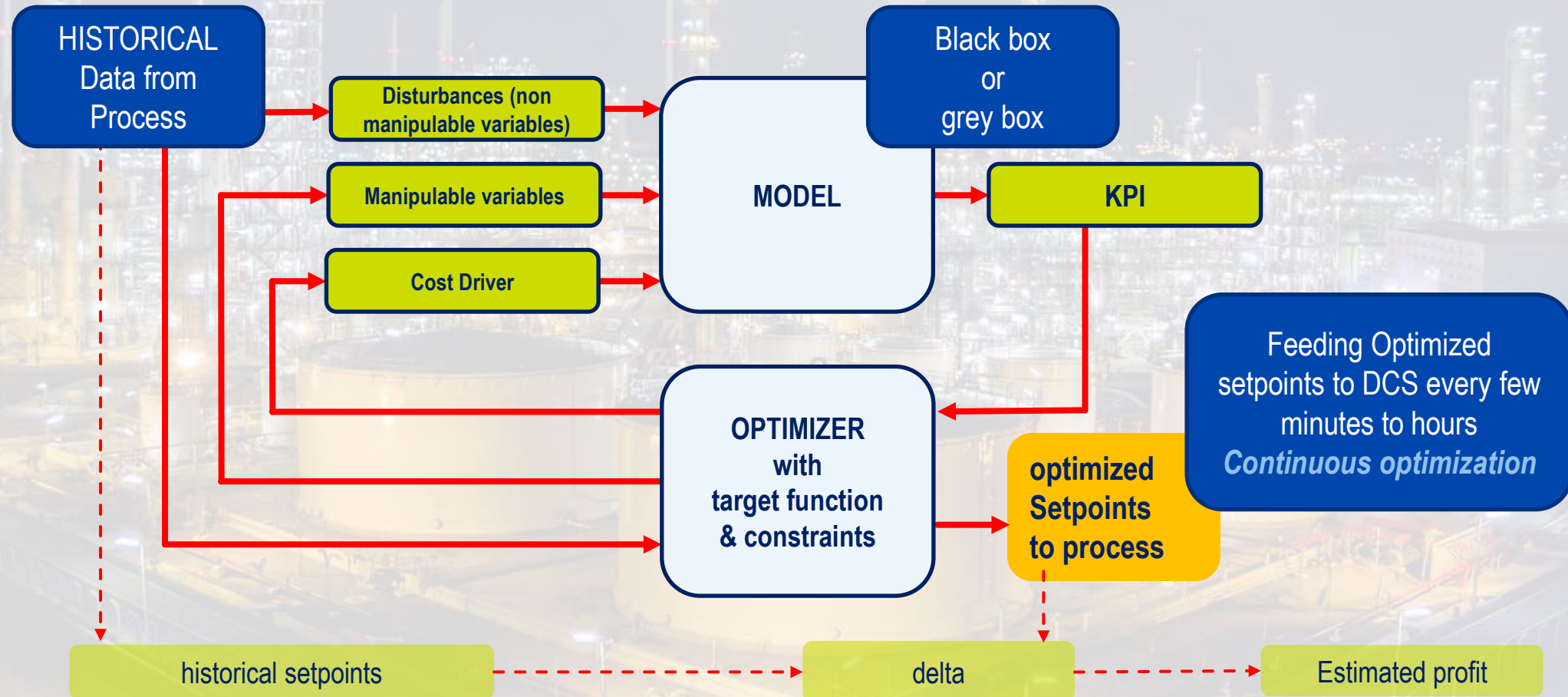
optimization reduces variability by factor 10 →  
**higher production rate, more stabil process, lower costs**





# Optimization of operating parameters using Machine Learning

Optimization using model and optimizer:



# Summary

- Goal of OPEX4.0 is a safe plant, running at stable conditions with optimized economic performance
  - Target function ‘minimized costs’ or ‘maximized Ebit/hr’
- Synergies of HAZOP and ML/AI based operational optimization
  - Efficient preparation of data & documents (P&IDs, functional plans, operating data, etc.)
    - Strong overlap of required data & documents
  - Quality of HAZOP study improved by systematic use of the operational data from the optimization project
    - ‘Bad’ operating periods and plant upsets show the actual problems, which often cause safety incidents
  - More room for optimization and reduced risk of operational optimization through certification and exactly calibrated safety limits resulting from the new HAZOP study
    - Safety limits are fixed in awareness of the optimization effort, not more conservative than needed
    - Certification of optimization project according VDI3714
- Online tools can increase efficiency: Online ‘Readiness Assessments’ supporting the preparation phase



# TÜV SÜD - AI application family

- OPEX4.0
  - Optimization of a plant's operating/process parameters by means of AI/Machine Learning
  - Target functions 'minimized costs' or 'maximized Ebit/hr'
  - Following the recommendations of VDI3714 (execution of big data projects in production environment)
- HAZOP +
  - Synergistic combination of HAZOP and OPEX4.0
- AMAIS
  - Sensor based Asset Monitoring, AI supported
  - Plant integrity is monitored by permanent sensors (e.g. for corrosion, erosion, vibrations, fouling,..)
  - Sensor data evaluated by AI and visualized on a Dashboard



## Questions? Talk to us!

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**Add value.  
Inspire trust.**





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## BACKUPs

# Serviceprodukt HAZOP+



## Vorteile der Kombination von Sicherheitsbetrachtung HAZOP mit KI basierter OPEX Optimierung:

- In HAZOP einbezogen werden Ergebnisse der Betriebsdatenanalyse
  - Dies führt zur qualitativen Verbesserung der HAZOP, indem reale Probleme beim Betreiben der Anlage besser mit einbezogen werden
    - 'Schlechte Fahrperioden',
    - Ungeplante Abstellungen; Überschreitungen von Alarmgrenzen
- KI basierte Optimierung der Betriebsparameter berücksichtigt aktualisierte Grenzwerte aus der HAZOP
  - Dies führt zu erhöhter Sicherheit beim Optimieren, mit Parametergrenzen aus einer HAZOP, die das Optimieren bewusst mitbetrachtet
    - Sichere, aber nicht unnötig großzügige Sicherheitsgrenzen
- In der Vorbereitung benötigen beide Studien (HAZOP, Optimierung) stark überlappende Daten und Dokumente. Gemeinsame Vorbereitung spart Aufwand und Zeit



# Preparation of Documents and Data

- **Preparation of Data & Documents:**
  - **Latest HAZOP study, Seveso report**
  - **Updated P&IDs, PFDs, Process description, equipment data, MOCs,..**
  - **List of process safety events and incidents, plant upsets of recent years**
  - **Functional plans of control loops and Safety (SIL) loops; control concept**
  - **Batch: Process sequence and automation concept**
  - **Operating data of several years from the DCS**
    - **‘Good’ and ‘bad’ operating periods resulting from the analysis of the operating data**
  - **List of control loops with time percentage on ‘manual’ (in % of time)**
  - **Liste of activations of Z (SIL) -switches and mechanical pressure relieve devices**
- **Online tools increase efficiency**
  - **Online ‘Readiness Assessment’ supports preparation phase**

# Analysis, OPEX4.0



- **Reduced Risk of operational optimization through exactly calibrated safe parameter limits resulting from the new HAZOP study**
  - **In the new HAZOP study the limits of the safe operating window** are discussed in detail, in order to neither expand the **range available for Optimisation** into unsafe territory, nor to make it too narrow.  
**The safe limits are used as input for the operational optimisation**
    - The parameters, where the optimization benefits from going to the limits are identified in the dialogue with the optimization team:
      - E.g. higher temperature to accelerate a chemical reaction, or operation closer to the quality limit
      - Our expectation is that the safety margins can often be set somewhat narrower, which helps the to gain additional room for the optimisation
- **Safe parameter limits, up to date and reviewed** → **Safe optimisation**
- **Limits of the safe operating window not more conservative than necessary** → **More room for optimisation**



# Analysis, HAZOP



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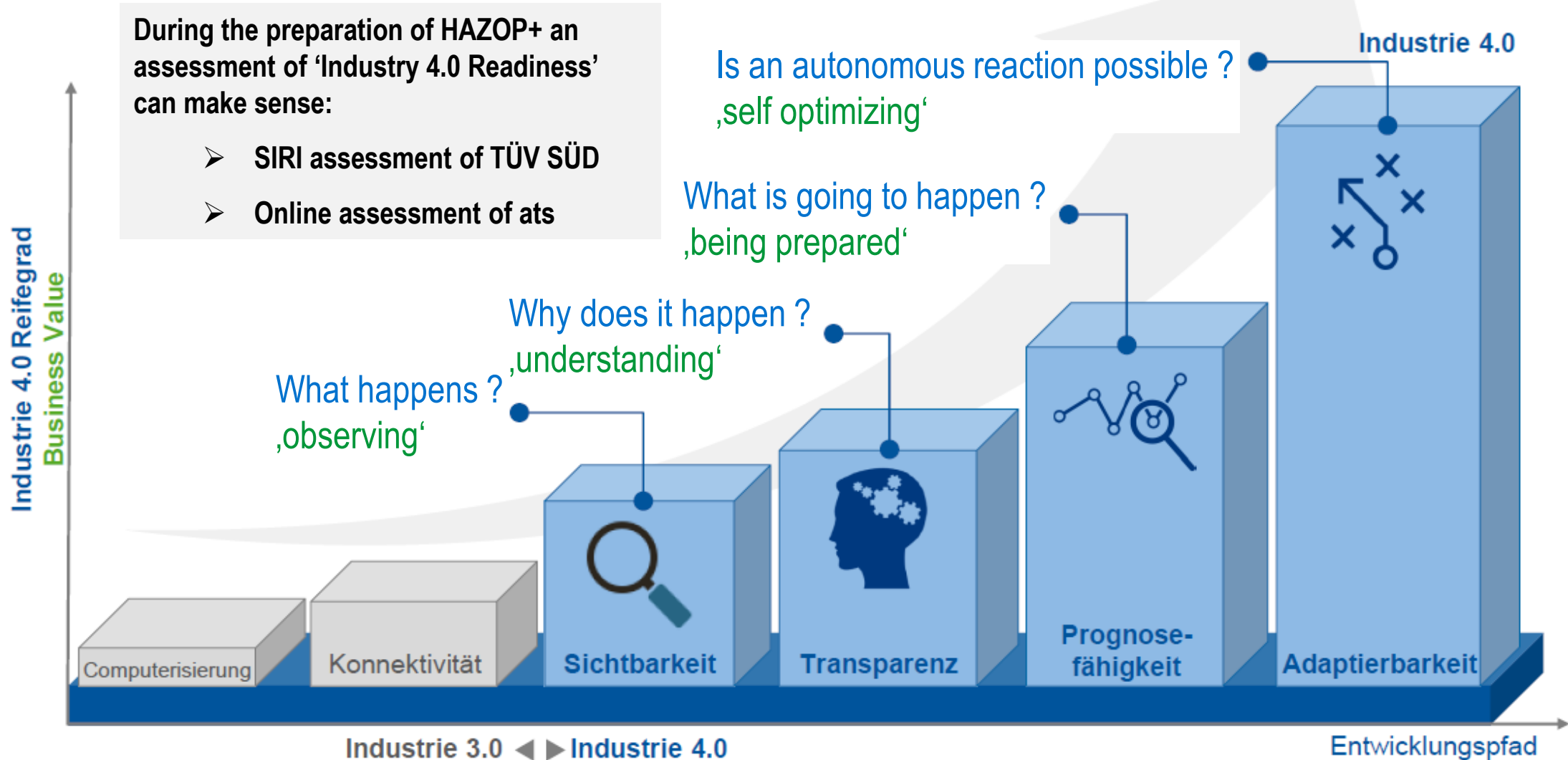
- HAZOP study makes use of results of the analysis of operating data performed in the optimization project
- This results in improved quality of the HAZOP study:
  - In the first step of the optimization, the operating data are analyzed in order to identify periods of particularly good/efficient operation, but also critical/bad operation as well as plant upsets
  - These critical periods of operation and upsets are used for qualitative improvements of the HAZOP study, by consideration of the real problems during plant operation (as opposed to looking only at design data)
    - 'Critical/bad periods of operation' from the analysis of operating data
    - Unplanned downtime, plant upsets
    - Events of exceeding alarm limits and safety thresholds

# Implementation

- **HAZOP:**
  - Implementation of HAZOP Action items through the operator company
  - TÜV SÜD support when issues arise during Implementation
  
- **OPEX4.0 Optimisation:**
  - The optimized operating parameters are manually entered into the DCS through operators or the atlan-tec software feeds them directly to the DCS ('closed loop')
    - Closed loop in time intervals of minutes to hours
  - The optimization models can be further improved with further production data
    - The model keeps learning (Machine learning)
  - Certification of the optimization project steps according VDI3714 through TÜV SÜD experts



# Industry 4.0 maturity levels



# Industry 4.0 maturity levels

Assessments of 'Industry 4.0 Readiness': SIRI (TÜV SÜD), Acatech (atlan-tec systems)

