Model Based Optimization in Process Control - Potentials and Challenges

Dr. Joachim Birk, BASF SE

The Chemical Company

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Model Based Optimization in Process Control
Outline

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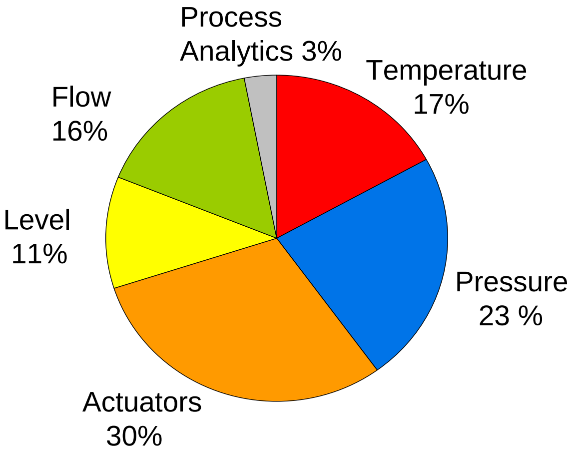
1. Status Quo in BASF
2. Success Stories
3. Vision
4. Challenges and Requirements

Status Quo in BASF Ludwigshafen (I)
Quantity Structure Sensors, Actuators, Control Loops



67.000 control loops

approx. 1.000 APC *)
(80% Advanced Analysis)
trend: + approx. 50 / a

potential for modelling support

approx. 100 Model Based Controllers

(95% model development specific for control)

460.000 instruments

*) Definition see papers from NAMUR WG 2.2

Status Quo in BASF (II)
Tendencies Supporting Model Based Process Control

- steady state models for most (new) plants
  - process development,
  - conceptual process engineering
- software for „dynamization" of steady state models
- relatively small but increasing number of dynamic models for complex plant units
  - operability analysis
  - startup sequences

  } complex dynamics by energy and material integration
- training simulators for some plants

Status Quo in BASF (III)
Tendencies Supporting Model Based Process Control

- comprehensive toolboxes for controller design
- Plant Information Management Systems (PIMS) for each plant,
  - **<u>all</u>** measurements available in long-term archives
  - ➡ basis for model identification, ...
- powerful DCS (direct realization of APC or interfaces to powerful systems)

➡ perfect infrastructure to implement and supervise model based controllers

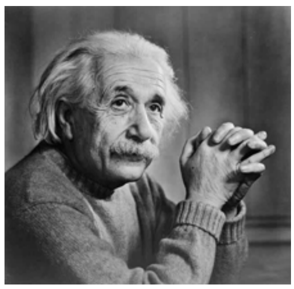
Status Quo in BASF (IV)
Development of Process Control Models

➡ main effort for applying model based controllers is modelling

➡ main challenge is limited number of available specialists for dynamic modelling

➡ need for software based modelling support

Albert Einstein:
„A model should be as simple as possible – but no simpler“



➡ a model should be as perfect as necessary
- modelling effort
- (implementation and) maintenance effort

➡ efficient modelling depends on
- required model scope and model quality
- already existing models for other purposes
- automation infrastructure

Status Quo in BASF (V)
Development of Process Control Models

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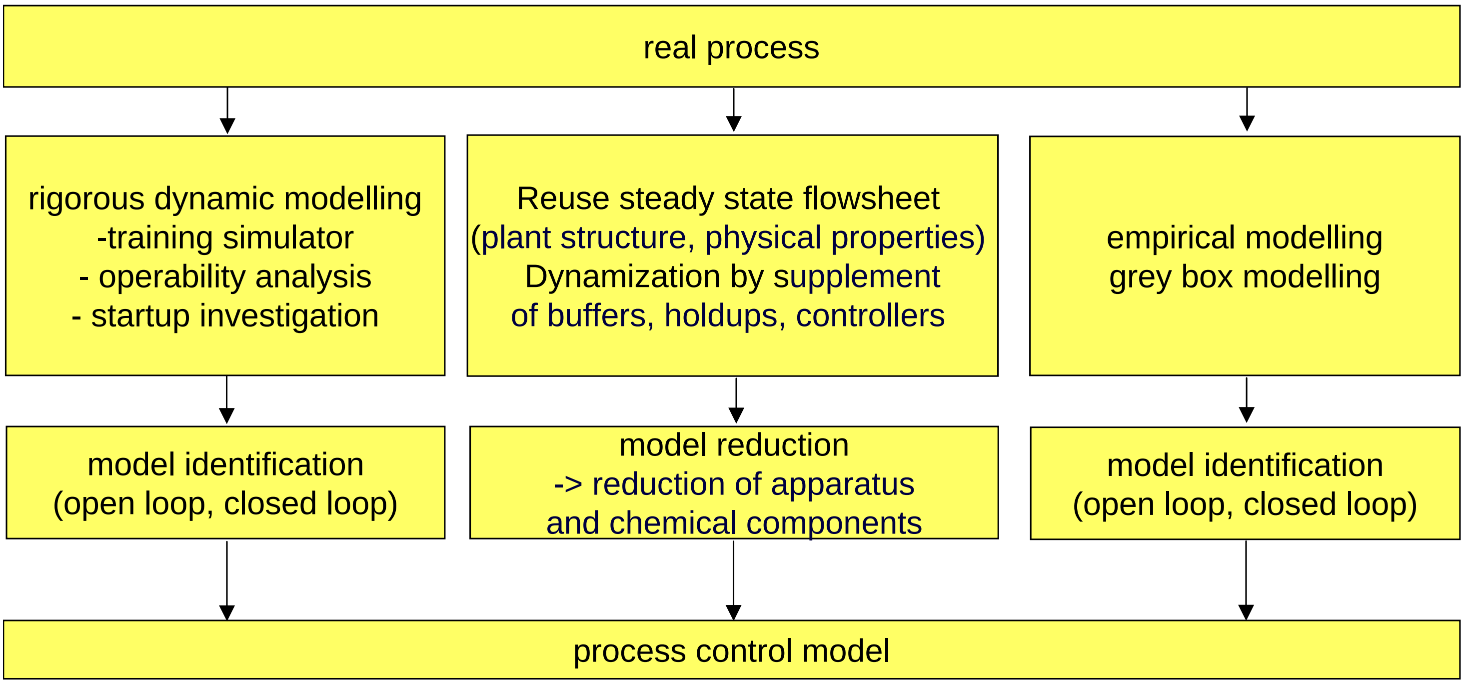

Success Stories (I)
Development of process control models

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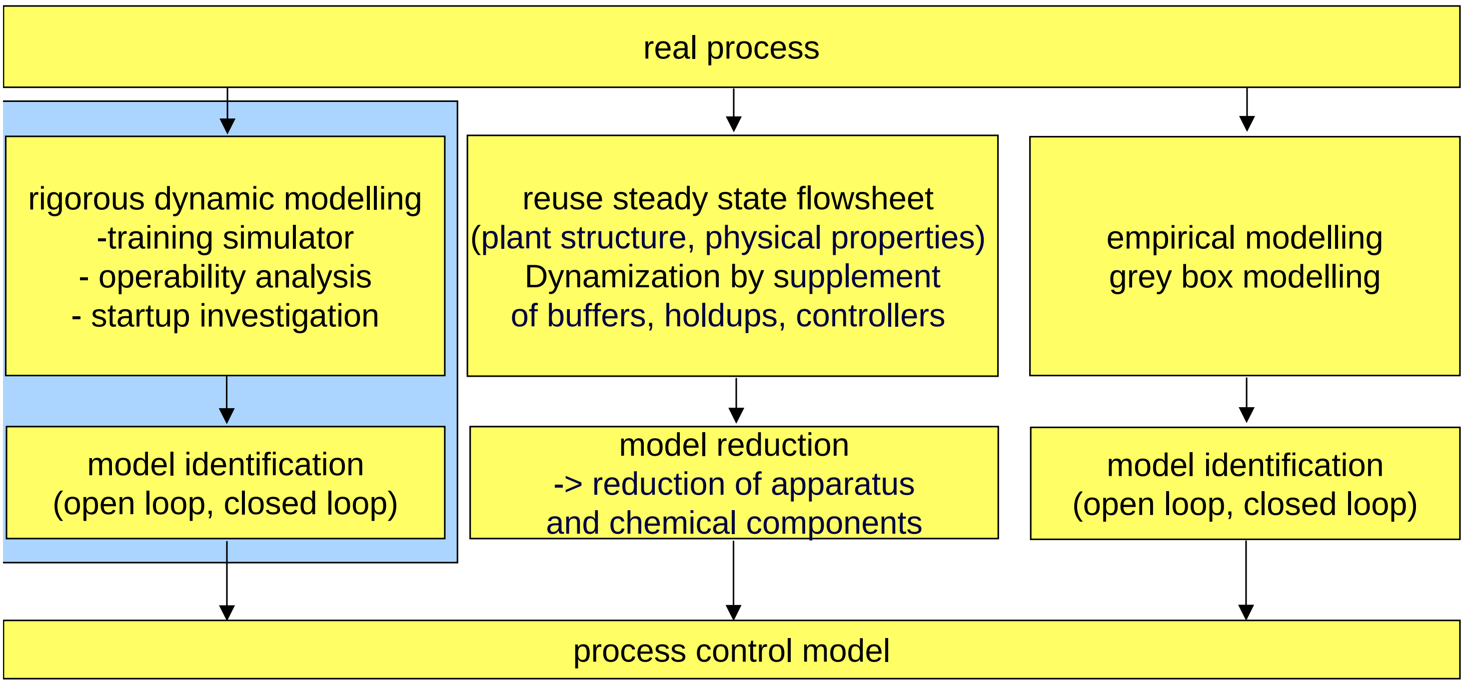
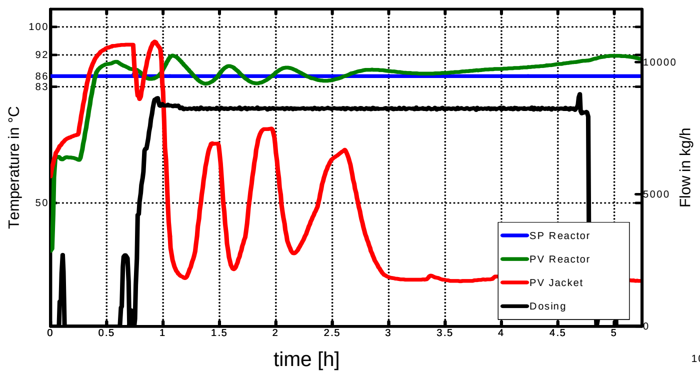
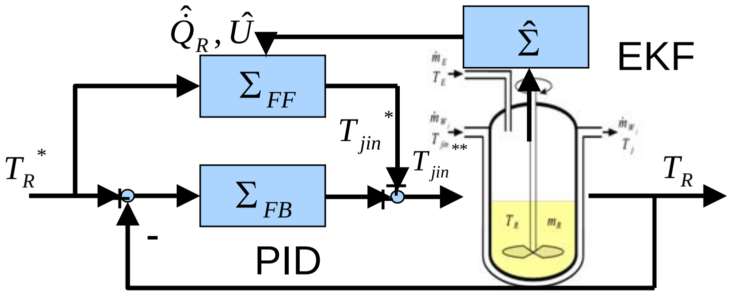


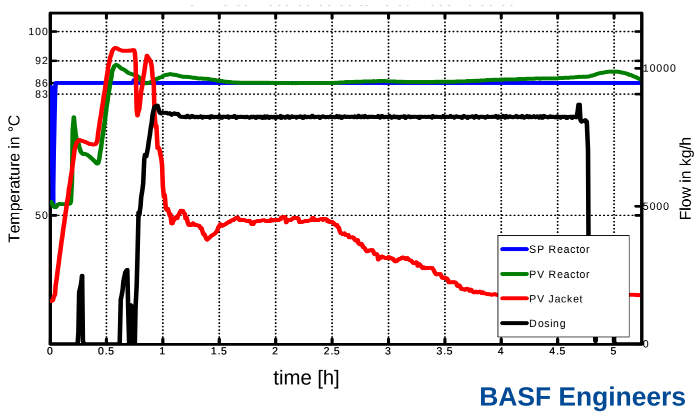
Success Stories (II)
Control of Semibatch Reactors

Initial situation: best PID control



modelling for **flatness based control**:
- Calorimetric reactor model
- Detailed model of cooling system



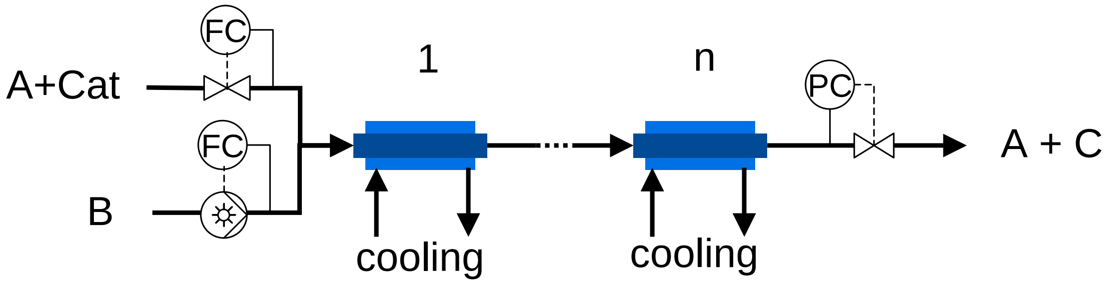


Success Stories (III)
Flatness Based Control of Semibatch Reactors

- flatness based control of semibatch reactors enables
  - significant better temperature control
  - higher reproducibility of batches
  - significant batch time reductions

- high control performance requires high state estimation quality ➡ detailed modelling of cooling system necessary ➡ model reduction
  - orthogonal collocation for cooling systems with constant coolant flow rate
  - finite differences for fluctuating coolant flow rate

Success Stories (IV)
Control of Plug-Flow Reactor

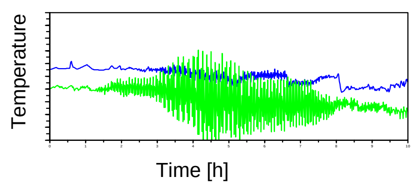


problem: heavy oscillations e.g. after load changes

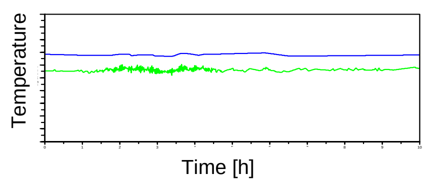
cause: strong dynamic coupling between flow and conversion

solution: model based analysis and robust control

initial situation

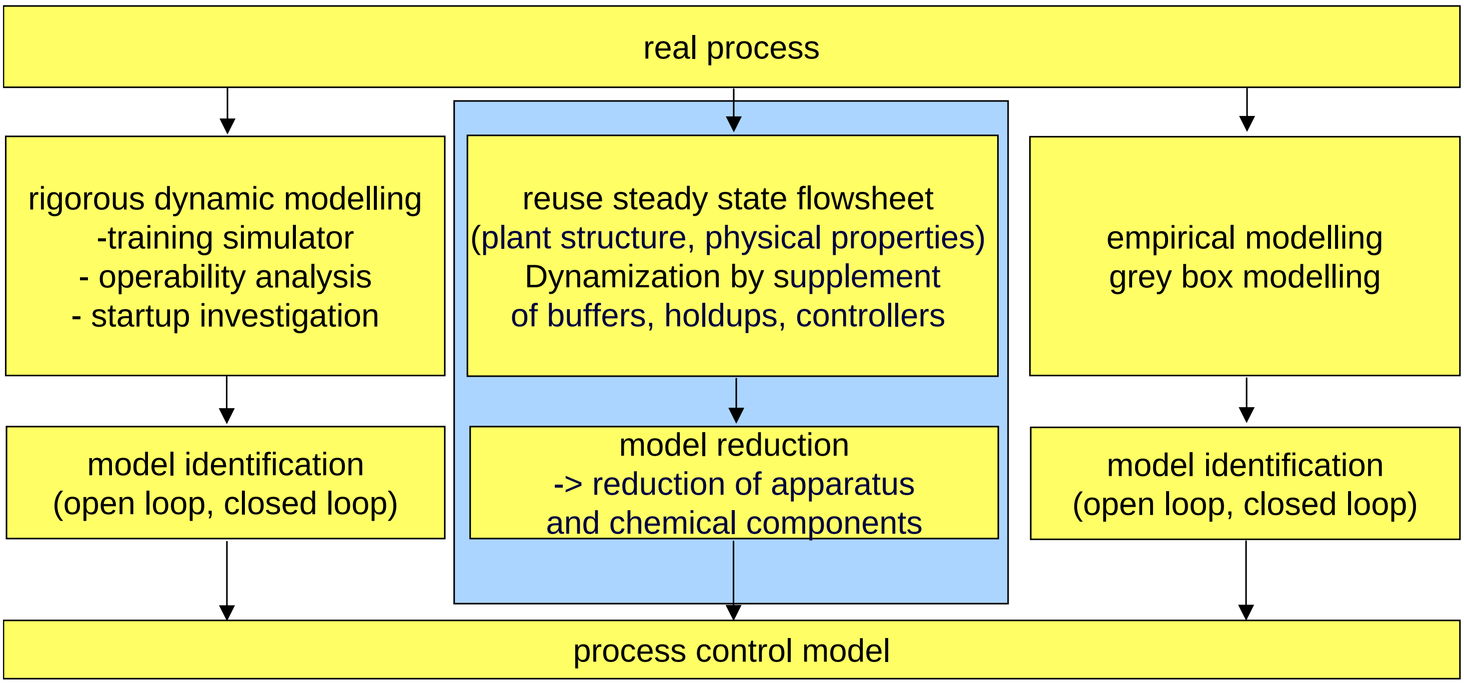


new control



result:
+ 8% capacity

Success Stories (V)
Development of process control models



Success Stories (VI)
Dynamic Simulation for Design of Process Control Concepts

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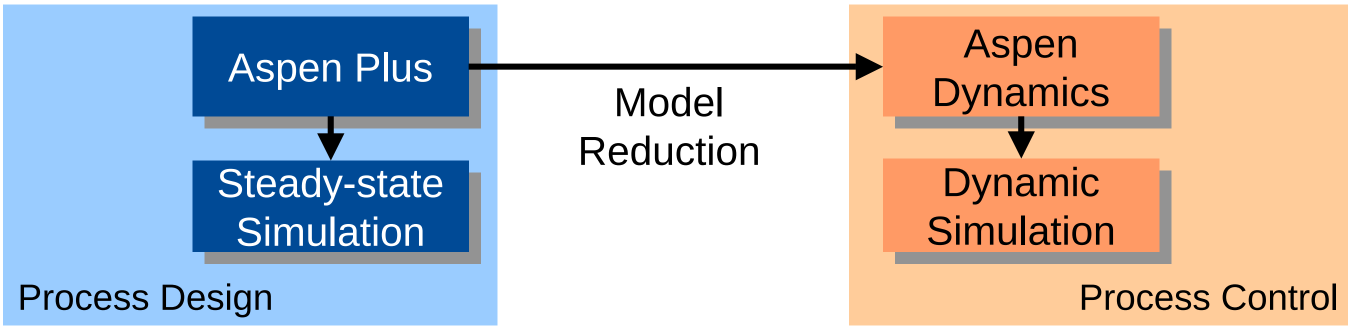

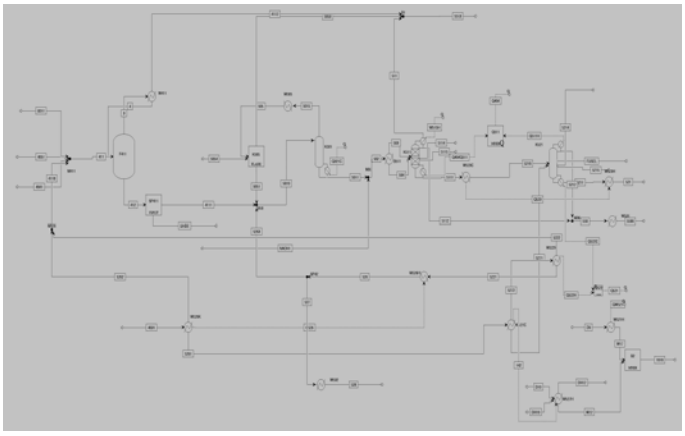

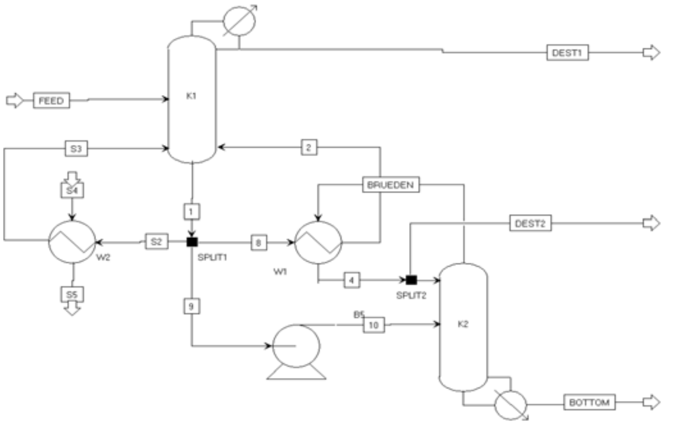

Success Stories (VII)
Control Concept for Energetically Coupled Columns

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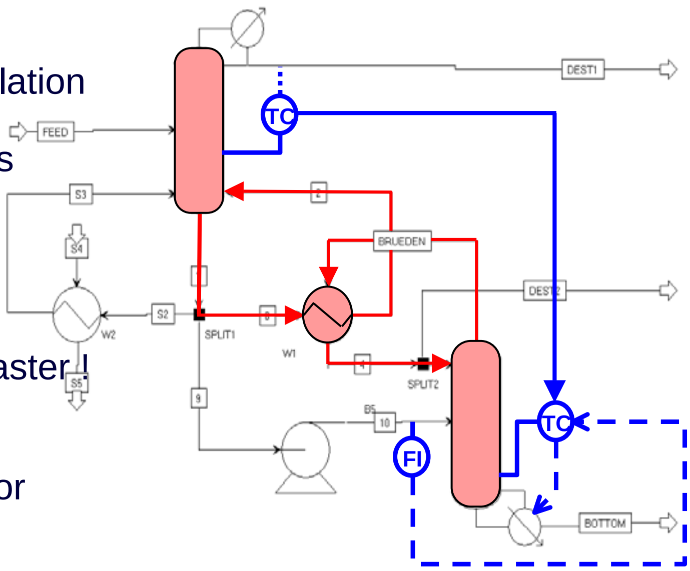
- Starting point: steady state flowsheet
- Aim: efficient development of dynamic simulation
- Comparison:
  - reuse of plant structure, physical properties
    supplement buffers, holdups,
    manual reduction of apparatus
    and chemical components
  - reuse only pyhsical properties
    reimplement simplified process model -> faster !
- Dynamic modelling 10x faster as 2000

- Advanced analysis ⇒ 2 PID + 2 injections for approximate decoupling
- Consideration of control concept in early phase of plant engineering



Further need: Configurable model transfer
from steady state flowsheet to dynamic simulator -> model reduction

Success Stories (VIII)
Development of process control models

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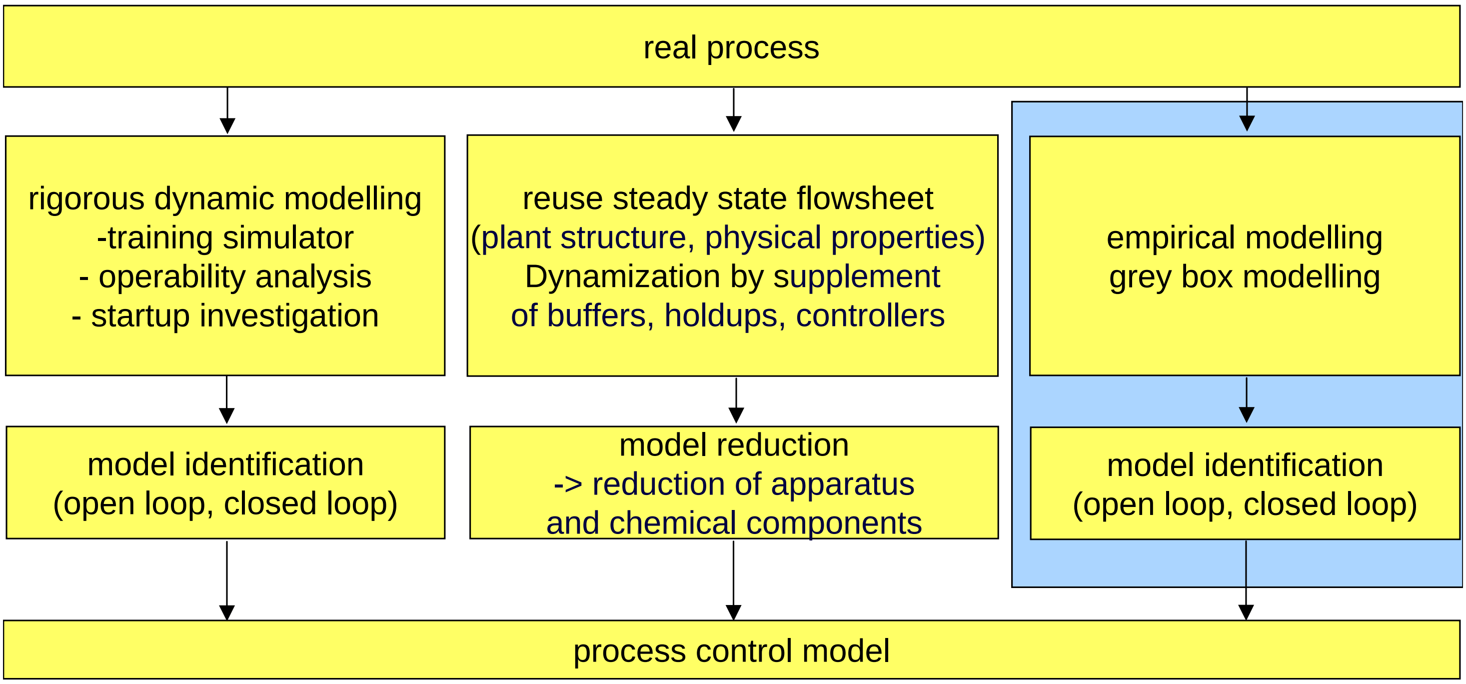

Success Stories (IX)
Model identification

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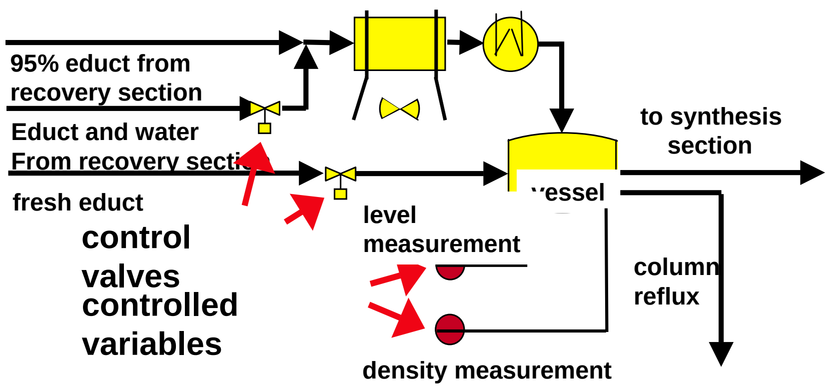
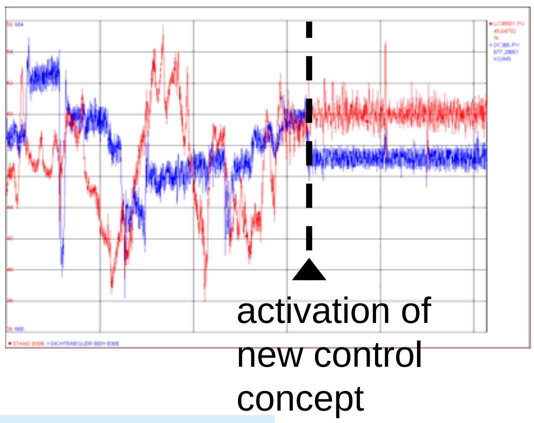
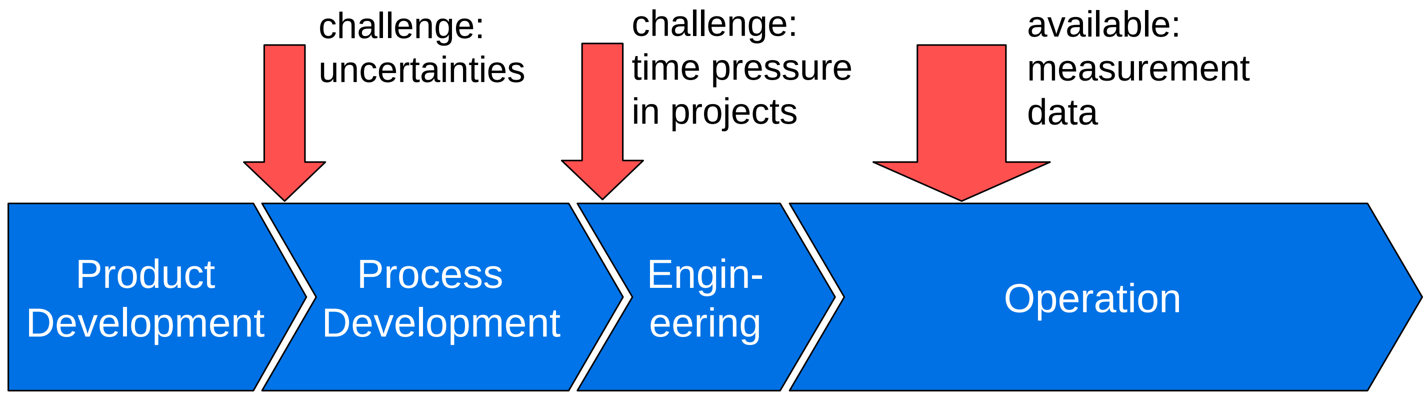




- Controlled variables: density, level
- Manipulated variables: valve positions for educt and water supply
- Linear 2x2 model derived from historical PIMS data
  - closed loop identification
  - without step tests
- New controller delivers significantly reduced variance

➡ No need for more detailed model or more effort

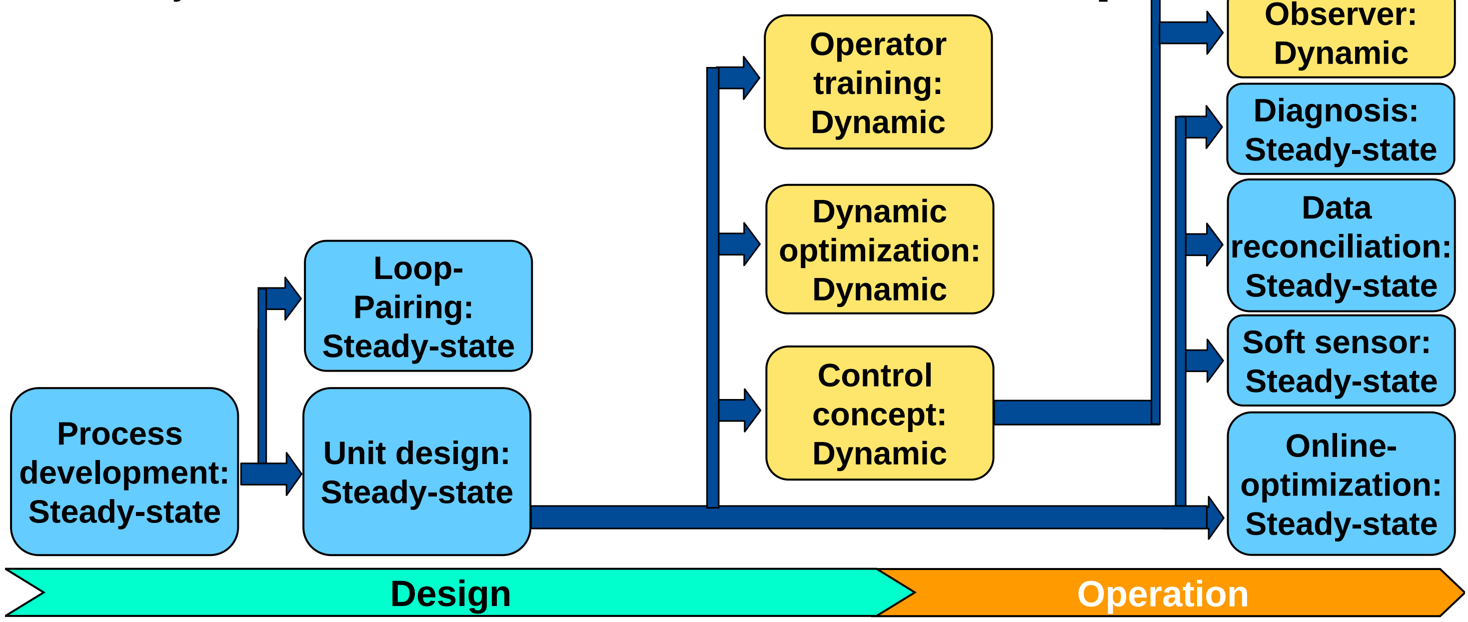
Model Based Control in Life Cycle of a Process



➡ Contributions to Operational Excellence in all phases

Vision: Efficient Re-Use of all Model Information by Consistent Model Database

Models Used During Life Cycle
[Bausa, Dünnebier: Life Cycle Modelling in the chemical industries: Is there any reuse of models in automation and control? ESCAPE 2006]



Challenges and Requirements (I)
Aim in industry: Maximization of added value
Modelling requires trade-off between

- modelling effort
  - integrated software platform
    – steady state simulation, dynamic simulation, model reduction and identification, controller design
  - pragmatic „80/20“ approach

- model transparency for different target groups
  - design engineers
  - maintenance engineers
  - operators

- model accuracy and robustness
  - online model check
  - event based model updates
  - fallback concepts

- model maintainability in plant life cycle (especially plant changes, ...)
  - complexity
  - ownership of models (Responsibilities are spread over the organization)
  - life cycle of modelling, simulation and control software -> compatibility for years

Challenges and Requirements (II)

- In Process industry,
  Process **c**ontrol starts with a capital <u>P</u> and a small <u>c</u>

- Important to understand first the process
  and then to start with the control part

- Need for
  - intelligent software
  - qualified process engineers from universities

  ➡ modelling know-how

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