LISTEN.
THINK.
SOLVE.®

Achieving & Sustaining Manufacturing Excellence with Model-Based Predictive Control (MPC)

Pavilion8 Production Optimization

Koen Louagie

Rockwell Automation At A Glance

Leading global provider of industrial automation control and information solutions

- Annual Sales: $6 billion
- Trading Symbol: ROK
- Employees: About 20,000
- Serving customers in 80+ countries

Rockwell Software – At A Glance

Rockwell Automation

- Mission
  - Providing the world's leading model-based software to improve our customers' profitability
- Founded in 1991
  - Combined intellectual property of DuPont and Eastman Chemical Company
- Global Presence
  - Offices in North America, Europe, China, and Pacific Rim RA Pavilion Company Snapshot 3
- Financials
  - A division of Rockwell Automation, Inc., a $6 billion industrial automation company serving over 80 countries
- Commitment to Innovation
  - Team of researchers, computer scientists and industry experts leveraging more than 190+ patents in the field of modeling, control and optimization

FrieslandCampina
Unilever
sabic
lyondellbasell
INEOS
GE Plastics
ALCOA
Braskem
NOVA Chemicals
HUNTSMAN
bp
Fonterra
Dairy for life
CORN
Chevron Phillips Chemical Company LP
BUZZI UNICEM

Rockwell Acquisition - November 2007

Rockwell Automation

PAVILION® TECHNOLOGIES

Leadership In Automation and Information Solutions

Solution Provider

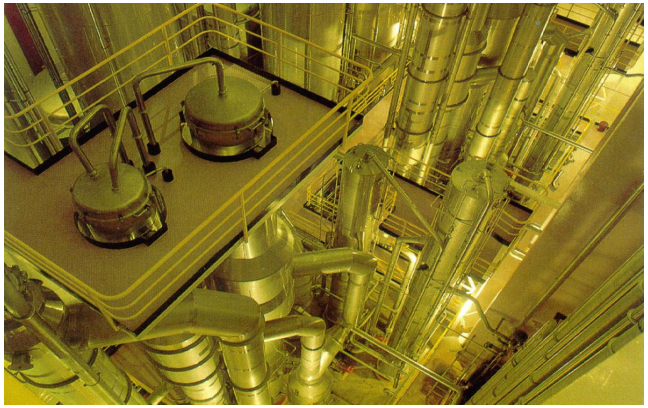
Global Presence

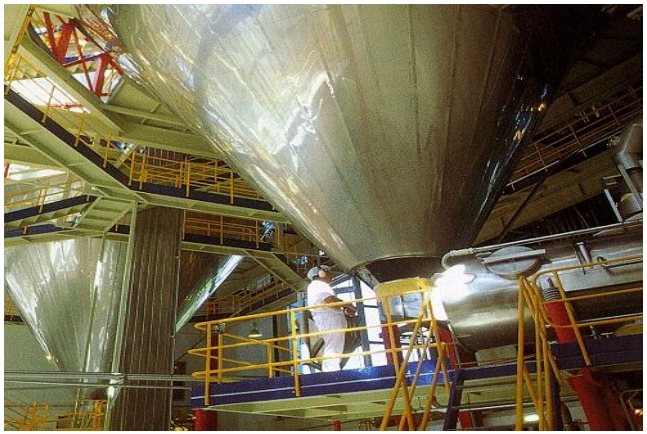
Leadership in Model-Based Software

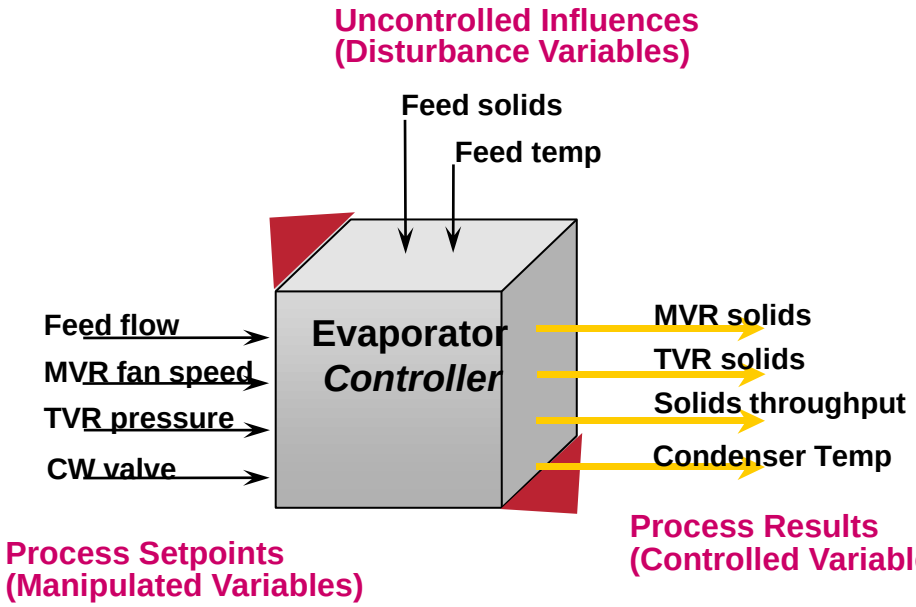
ValueFirst® Methodology

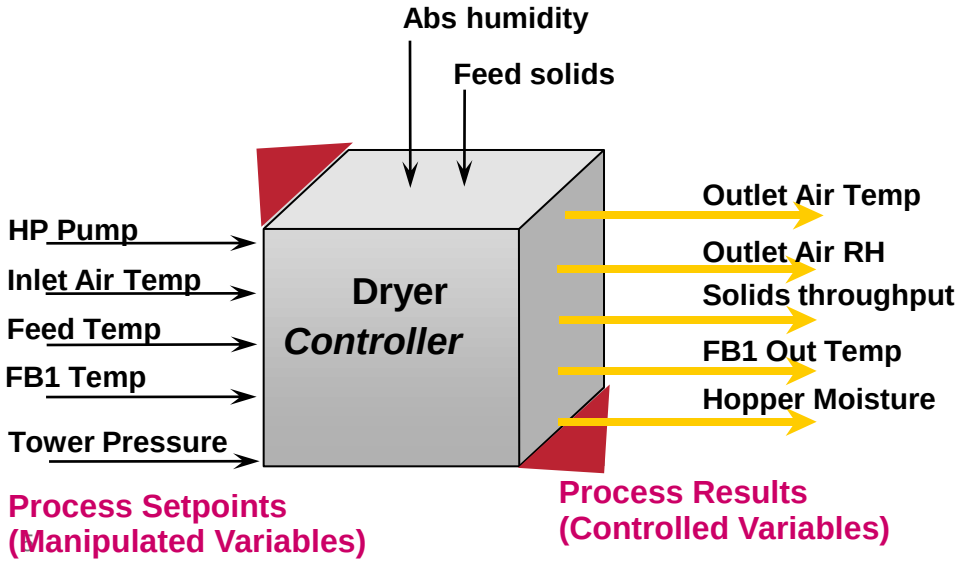
Expertise in Multiple Vertical Industries

Pavilion8 – Typical MPC Control Architecture









Challenges

- In their strive for manufacturing excellence, irrelevant of the process industry, companies deal with many influences on their plant operation:
  - Changing operating conditions due to changes in planning
  - Variations in quality of raw material
  - Changing ambient conditions
  - Last but not least: impact of operator interventions
- Situation in control room:
  - Due to high level of interactions and disturbances in the process:
    - Difficult for operators to predict what the exact effect is of changes they apply
    - Result: operators operate the plant in most cases in stable but suboptimal working point
    - Once stable operation achieved, operators not very eager to push the plant towards the optimal working point
- Due to highly interactive properties, operator can easily make incorrect changes that introduce upsets instead of bringing the plant closer to optimal working point

First: The confusion - What is it not?

- APC: Advanced Process Control
  - A term widely used for a variety of solutions that improve the efficiency of plant operations
  - By some parties referred to as (complicated) cascades of PID loops in the DCS -> this is ARC (Advanced Regulatory Control), not APC

- APC is a layered solution which includes optimized PID controls (at the DCS level) and a supervisory control system which utilizes a model of the plant (hence the term MPC: Model-based Predictive Control)

Hierarchy of Process Control Strategies

- Manual, On/Off, Open loop

Manual

- Ratio
- Feedback – PID
- Cascade
- Feed forward (multivariable)

Automatic

Optimize loop performance

- **Model Predictive Control (MPC):**
  - **Minimization of variation, energy…**
  - **Maximization of yield, throughput…**
  - **Inferential sensors**
  - **Model predictive control**

Calculate loop set-points!

Optimize process performance

PID Loop Control vs. MPC

- Best practices in automated control of process plant is applied:
  - To reduce frequency at which excursions happen as result of disturbances or sub-optimal operator intervention
  - These best practices range from optimized base layer controls (PID Loops at DCS/PLC level) to complete auto-pilots for the entire plant (using MPC)

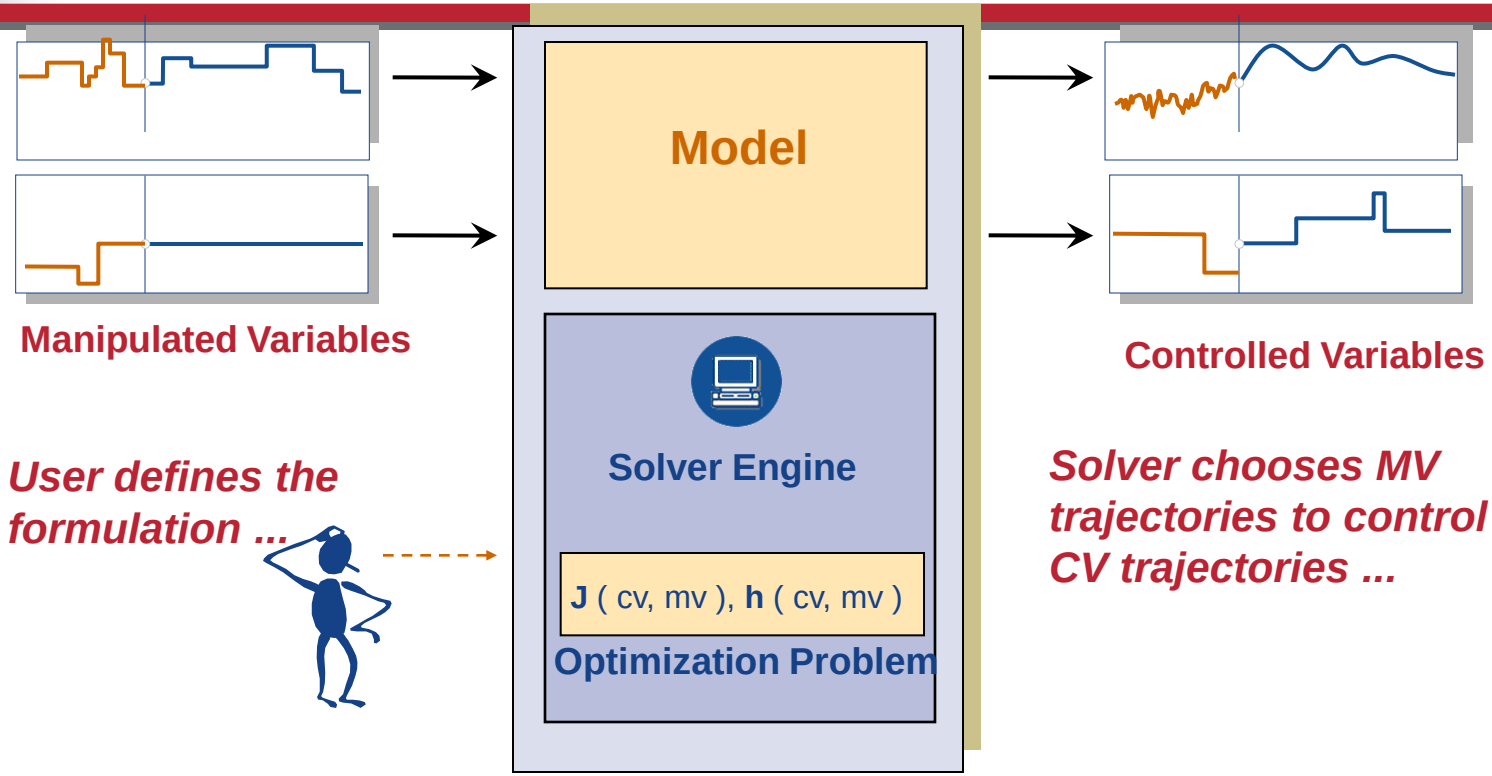
- PID Loops vs. MPC
  - PID Loops:
    - By definition local controllers, in general control 1 process parameter with 1 process handle
    - Cross effects between individual PID loops will not be known by either of the PID loops
    - As the process is hardly ever this straightforward we can state that the extent to which PID loops can help control the process has its limitations

PID Loop Control vs. MPC

- Added value of applying MPC technology on top of optimized base layer control comes from 3 aspects:
  - MPC applications are multivariable which means that they are capable of considering the entire process including all its interdependence
  - MPC applications are predictive which enables them to look into the future to evaluate where the process is going and decide not just based on the past but also on the predicted future how the key parameters need to be adjusted
  - MPC have the capability to automatically steer the process towards its economic optimal point of operation, whilst ensuring that key process parameters stay within operator-or engineer defined limits

→ None of these powerful functionalities can be implemented with just base layer control

Process Control Models



Internal model of plant used to

- optimize setpoints for steady-state operation
- predict plant behavior given input actions
- simulate plant off-line to tune controller

Non-linear steady-state model

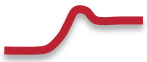
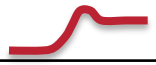
- historical data from multiple operating regions

Linear dynamic model

- based on SISO or MIMO step tests of the plant
- portions of dynamic model user specified

What is a Controller Matrix?

A typical controller consists of a matrix of process models that explain all important interactions in the process

	CV1	CV2	CV3
MV1			
MV2	No Model		No Model
MV3			
DV1			
DV2			No Model

The completed MPC model will allow the controller to PREDICT the values of the CVs by movement of all the MVs and DVs. Hence PROACTIVE control can be taken to achieve the CVs setpoint before the they are violated, hence reducing variability

How does MPC makes money

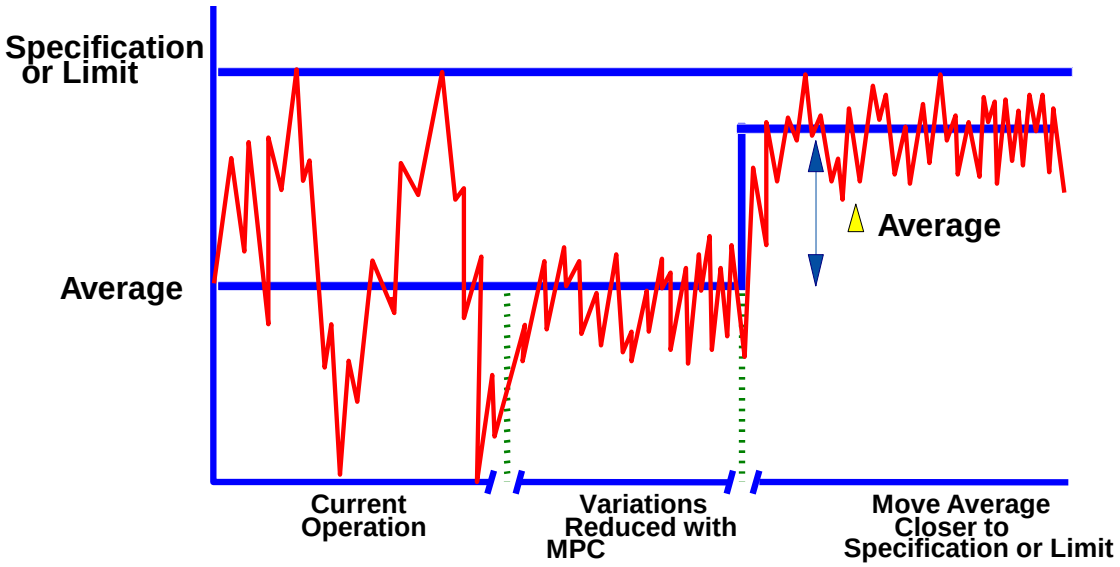
How MPC Enables Operational Objectives

Step 1: The MPC application reduces variances in key process variables.

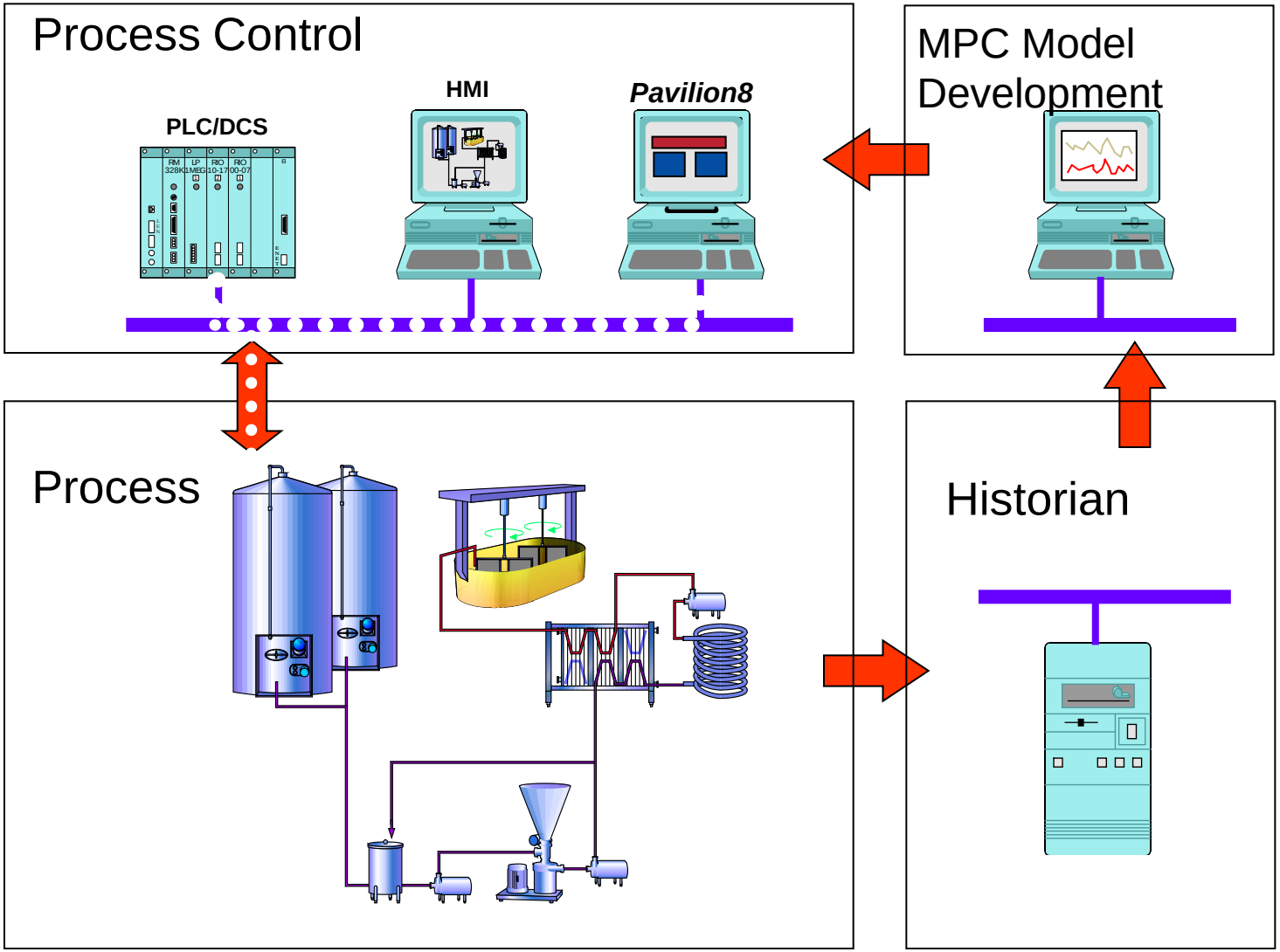
This is achieved by tighter control of the key process handles

Step 2: Reduced process variations allow the unit to be run closer to its limits

This allows higher production averages, lower energy consumptions, etc…



Where MPC Fits in Plant Automation Environment



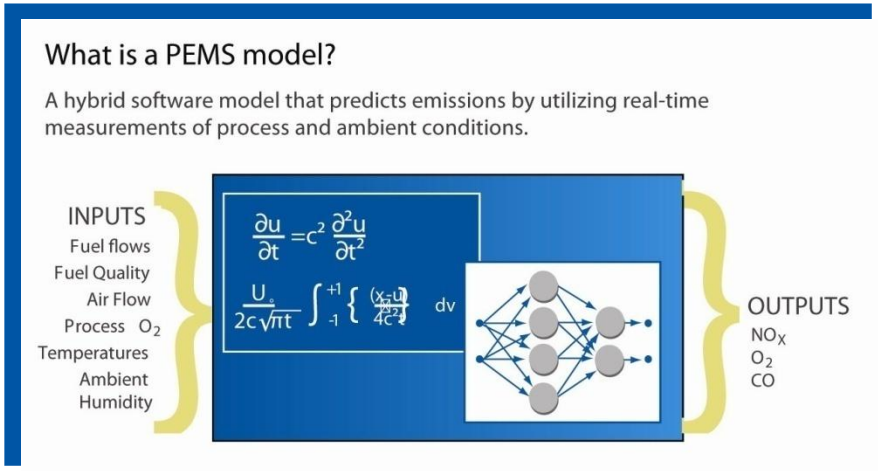
Why Use Pavilion8?

- Provides non-linear MIMO control
- Internal models combine;
  - Historic data,
  - Step test data and
  - First Principles Models, etc
- Leverages existing DCS infrastructure

Solution – Software CEM®

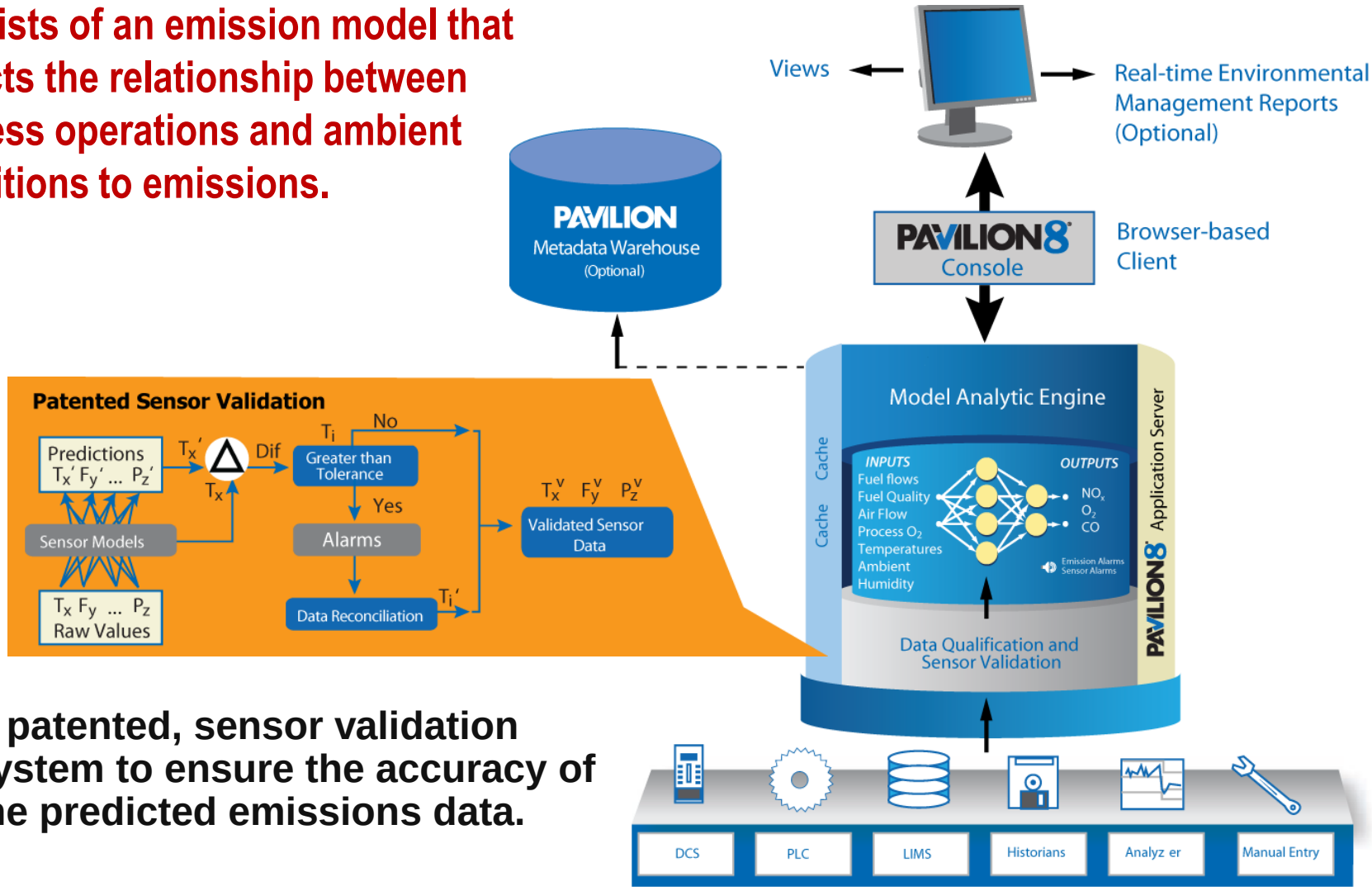
A patented, nonlinear hybrid model-based, Predictive Emission Monitoring System (PEMS) that provides an alternative to hardware-based Continuous Emission Monitoring System (CEMS).

- Meets all performance criteria for regulatory certification
- Cost effective solution powered by Pavilion8™ software platform
  - Same platform for Model Predictive Control & Optimization
- Rockwell Software is an active expert in technical support to regulatory agencies worldwide.
  - Patented - 1st introduced in 1993
  - Over 250 installations in diverse applications



The Pavilion Software CEM® Solution

Consists of an emission model that reflects the relationship between process operations and ambient conditions to emissions.



A patented, sensor validation system to ensure the accuracy of the predicted emissions data.

Software CEM® Advantages

Cost Effective Monitoring & Compliance

- A proven, model-based, software solution that leverages ***existing*** process instrumentation and data
- Does not require additional capital equipment or real estate
- The average Software CEM costs approximately 50% of a Hardware CEM system with yearly operating costs at approximately 20% of a Hardware CEM system

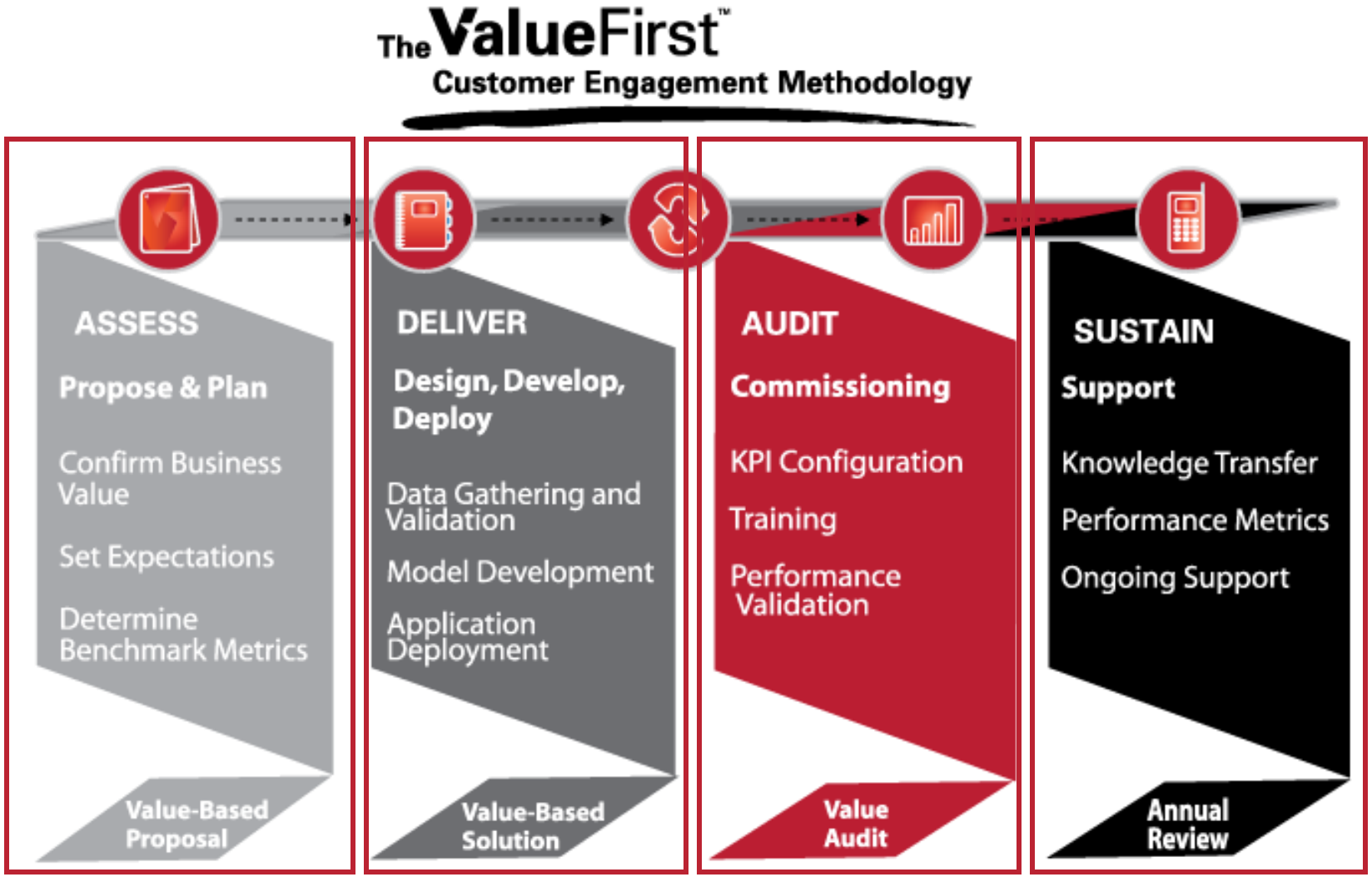
Highly Accurate & Reliable Emissions Monitoring & Reporting

- Detects & alerts operator to sensor failures
- Meets strict continuous emissions monitoring data availability requirements of 95% or more
- Continues to operate in the event of sensor/instrument failure
- Accurate emissions modeling with robust prediction capabilities

Environmental and Industry Experience & Expertise

- Proven solutions that meet unique, local regulatory requirements
- Provides added confidence and reduced risk exposure

How Rockwell Software Delivers Customer Value



Delivering Predictable Results.

Snapshot of References

- Case analysis - Unilever
  - Reduction in moisture & over drying Variability: 56% (50% expected)
  - Increase in Average Moisture: 0.76% (0.75% expected)
  - Reduction in BD Variability: 40%
  - Reduced out of spec product
- Case analysis – Fonterra
  - Increased production rates by 5–15%
  - Improved product quality by 50%
  - Increased energy efficiency by 5–12%
  - Increased product yields
- Case analysis – Arla Foods
  - Production Yield & Quality improvements
  - Primary driver: Revenue growth through…
  - 'Product mix / Capacity increase flexibility - to exploit high margin returns'
  - Energy Savings per tonne of product
- Case analysis – Friesland Campina
  - Yield increase by 0.68%
  - Capacity increase EV 2.3%, Dryer 3.5 %
  - Increased energy efficiency by 6-7%
  - Improved product quality by 50%
- Case analysis – Utilities & Energy
  - Reduce variability in generating equipment
  - Reduce costs/ton of refrigerant, chilled H2O, steam, compressed air
  - Avoid inefficient operation or unplanned outages
  - Ensure a reliable supply to meet production objectives

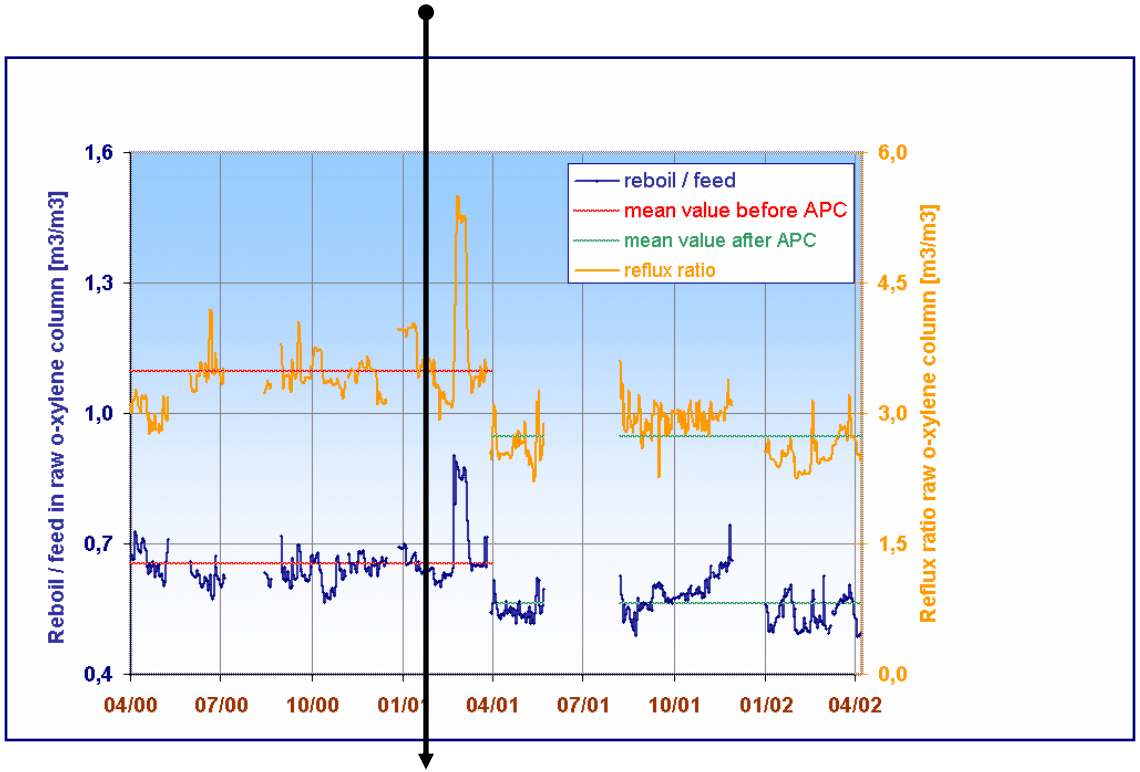
BP Gelsenkirchen Case Study
Customer Since 1998

Rockwell Automation

- Customer
  - Largest BP petrochemical complex
  - Gelsenkirchen, Germany Complex
  - Operates 3 Olefins Plants, Aromatics Unit, Cumene
  - Produces 1.3 MM Tonnes Annually
- Project Objectives – Aromatics Unit 5
  - Achieve quality specification targets on the Aromatics Unit
  - Reduce specific energy consumption
- Process Challenges
  - Wide range of operating conditions
  - Varying feedstock produced variation in product streams
- Pavilion Solution
  - Pavilion Chemical Control Solution
    - Distillation Control

bp

Reduced Specific Energy Consumption



BP Gelsenkirchen Benefits Delivered

Rockwell Automation

- Strong Operator Acceptance
  - Strong teamwork with site personnel
  - Ease of use of application
- Strong Controller Uptime
  - Online since 2001 (8+ years) delivering value
- Operational Benefits
  - Reduced specific energy use
    - Reduced specific MP steam consumption in extractive distillation
    - Reduced specific HP steam consumption in the xylene distillation
    - Increased MP steam production using condensation heat more efficient in the raw o-xylene column
  - Reduced o-xylene loss in the C9+ cut
  - Decreased NFM solvent / feed ratio in the extractive distillation column
- Continued Success
  - Pavilion is the APC standard for the entire petrochemical site
  - Includes: 2 Aromatics Units (unit 4 and 5), Olefins Unit

"The applications in the aromatics plant 4 have optimized production. We were able to reduce our specific energy consumption, while reducing our product variability. And this translates into significant bottom-line benefit for our company."
Dr. Georg Hautkappe
Production Manager
BP Petrochemical

bp

Summary

- Many manufacturing leaders have recognized the importance of process control as enabler for achieving and sustaining manufacturing excellence
- Yet, many are not taking the right steps to ensure that process control and automation is used to the extent possible
- A distinction has been made between the two levels of process control:
  - Base Layer Control (PID Loops)
  - Model Predictive Control (MPC)
  - The extent to which PID loops can help control the process has its limitations → added value of applying MPC on top of base layer control
- Rockwell automation has showed that MPC is a proven technology generated proven benefits in many industries
  - Adopted the right approach with ValueFirst methodology presenting customer:
    - Benefit assessment results
    - Investment required
    - Project scope, deliverables and timeline

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Any questions?