Lean Model Management for Production Environments

Formulation 4.0

13 December 2018

PERCEPTIVE ENGINEERING

Lean Model Management

Overview

Perceptive Engineering

- About Us
- Process Agility: Challenges and Solutions
- Model Development, Validation
- Model Management
- Model Deployment - Optimised Manufacturing
- Summary, Q&A

Lean Model Management

Perceptive Engineering

Who

- Industrial Advanced Process Control
- 25 APC Engineers
- Offices in UK, Singapore, Ireland

Where

- Pharmaceutical
- Consumer Packaged Goods
- Environmental (Clean & Wastewater)

Academic / Innovation Alliances

- Universities of Cambridge, Manchester, Newcastle, Rutgers, UCL, Strathclyde, Leeds, Surrey
- Centre for Process Innovation (CPI), Centre for Continuous Manufacturing and Crystallisation (CMAC), Institute of Chemical and Engineering Sciences (ICES Singapore), Research Centre Pharmaceutical Engineering (RCPE), Synthesis and Solid-state Pharmaceutical Centre (SSPC)
- Industrial partnership with Siemens and GEA

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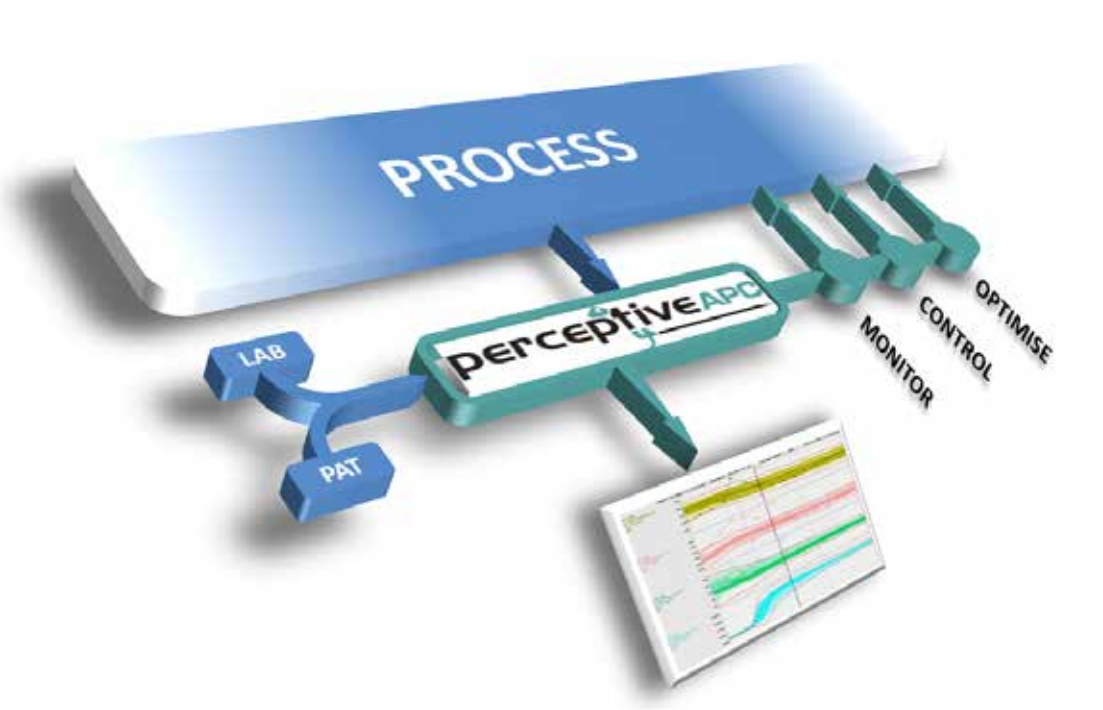
PerceptiveAPC Software Platform



- Data Import/Export
- Data Quality Monitoring
- Data Analysis
- SPC Monitoring
- Multivariate Modelling
- Multivariate Process Monitoring
- Multivariate MPC
- Continuous / Batch Optimisation

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Process Agility: Challenges

Spectrum

- Bulk powder production: 1 product equates to >90% of annual tonnage
- High-value manufacturing: multiple grades or recipes in 1 day
- **Need**: re-task production assets as quickly as possible (just-in-time manufacturing)

Distributed Data

- Process and Quality data generated per product, per variant, per process line, per plant
- No global historian?

How To

- Manage the complexity of multiple recipes, multiple raw materials, multiple CQAs
- Define impact of multiple variables from time-separated production runs
- Keep process models up-to-date
- Avoid compromise:
  - Why can’t we have efficiency, energy saving and waste reduction at the same time?

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Process Agility: Solutions

Model what you're making, not just what you're making it with

- Statistical modelling lets us predict end quality properties
- The prediction is another feedback signal into control of the process
- Digital model of the process: what to change, when, by how much, ahead of time

Cloud computing can bring people, data and models together

- Secure data storage
- Ease of access
- Appropriate model selection – a global MES

Context-driven machine learning keeps models updated

- Models updated as needed
- Context ensures models remain fit-for-purpose
- Machine-learning can learn the wrong thing (ever bought an Amazon suggestion?)

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Process Agility: Solutions

Pharmaceutical

- Traditionally batch: add everything, mix and react, test at the end
- PAT devices provide insight into batch development
- Model-based optimisation
  - batch endpoint prediction, batch trajectory control

- Now moving to **continuous manufacturing** for **personalised medicines**
  - PAT and digital models provide detailed understanding
  - Predictive models enable on-the-fly adjustment
  - True agility: assets tasked with continuously changing recipes

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Development and Validation

Formulated Products

- Multiphase complex liquids
- CQA only available after ALL ingredients are added, mixed, blended
- CQA highly influenced by variations in
  - process design
  - operational parameters
  - raw material quality

Modelling

- First, model process responses
- Second, model impact of raw material variability on quality
- Third, ensure the models are robust enough for industrial application

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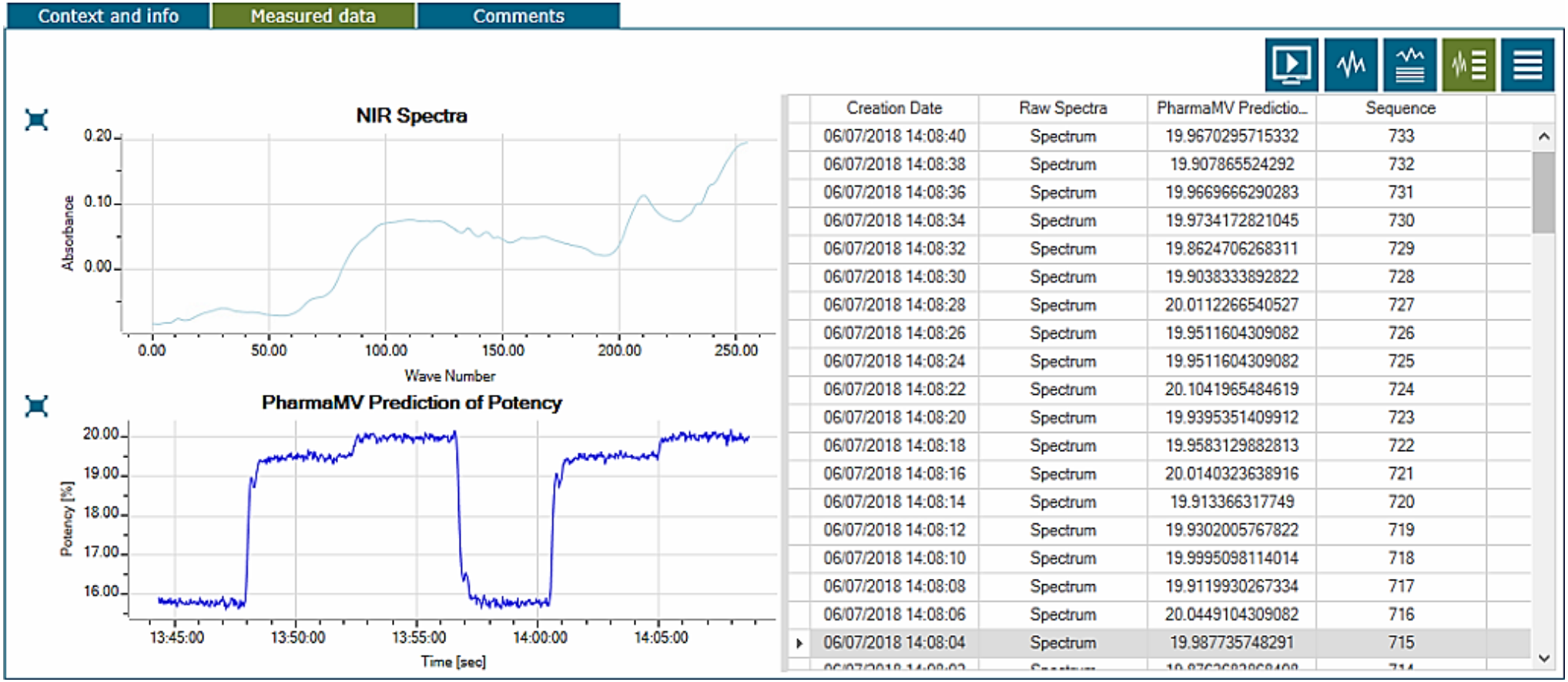
Development and Validation



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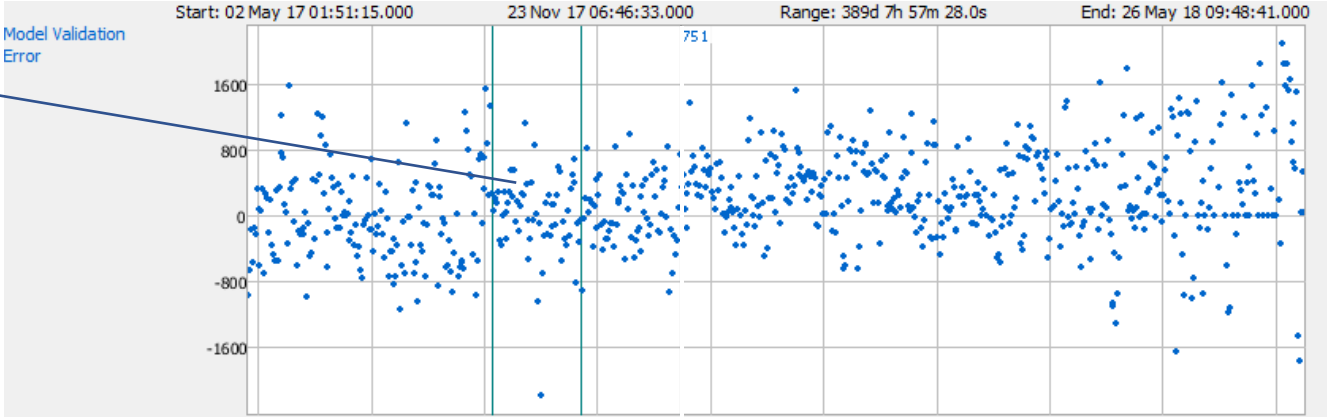
Development and Validation

The most common mode of failure for an online model is prediction ‘drift’

The easiest way to detect this is with a CUSUM chart

Rapidly identify point at which model needs to be re-tuned



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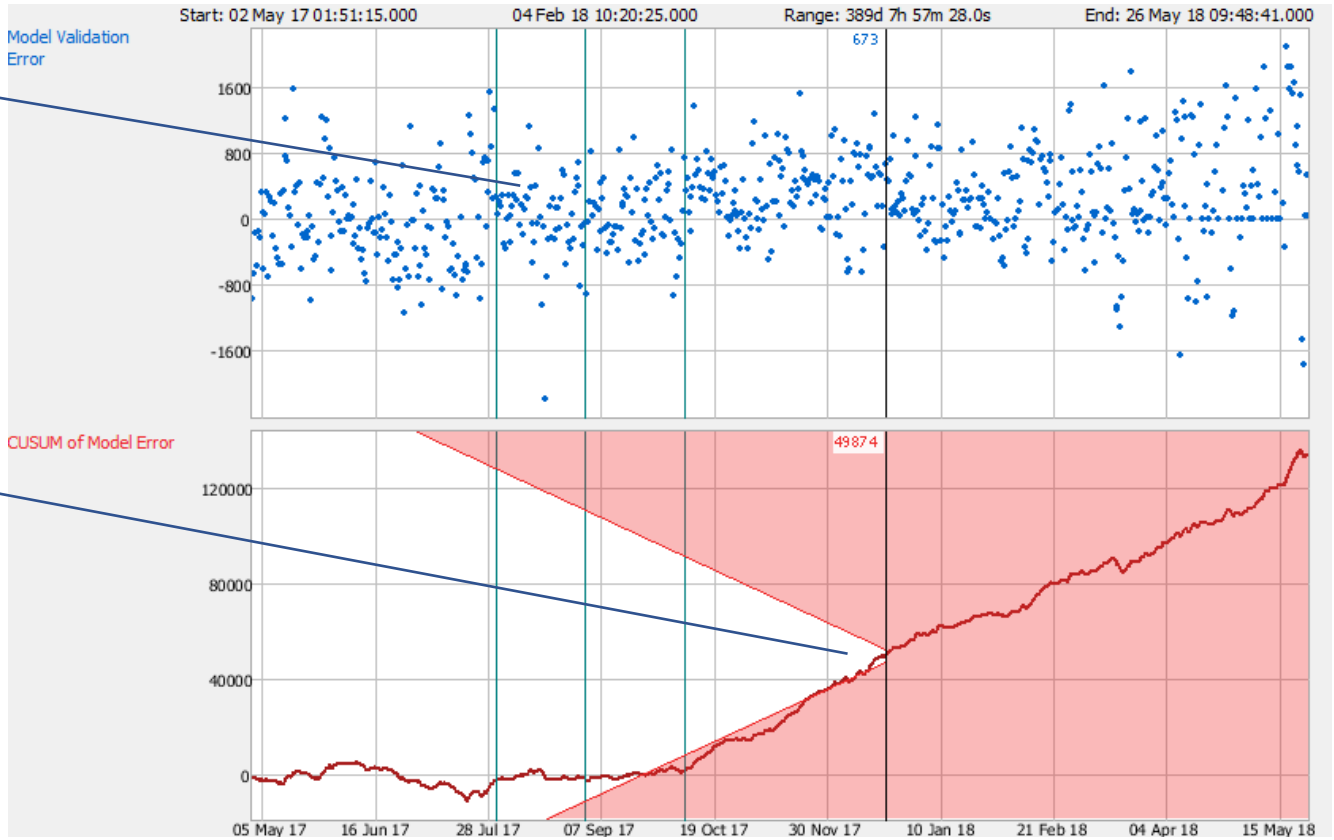
Development and Validation

If the CUSUM history fits within the 'jaws' of the VMask, then all is well

If CUSUM history is outside the VMask, model has drifted significantly – **action is required**



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Adaptation

Where do we Adapt?

- **New process** – no knowledge – needs human-input model development
- **Existing process** – scale-up, new product variant, process change – model may not fit

What do we Adapt?

- The control algorithms don't need to be changed, just how they are used
- The model needs to be changed, to provide better predictions to the controller

Why do we Adapt?

- No engineering resources to start from scratch
- No testing time available

Machine Learning

- Unsupervised model development

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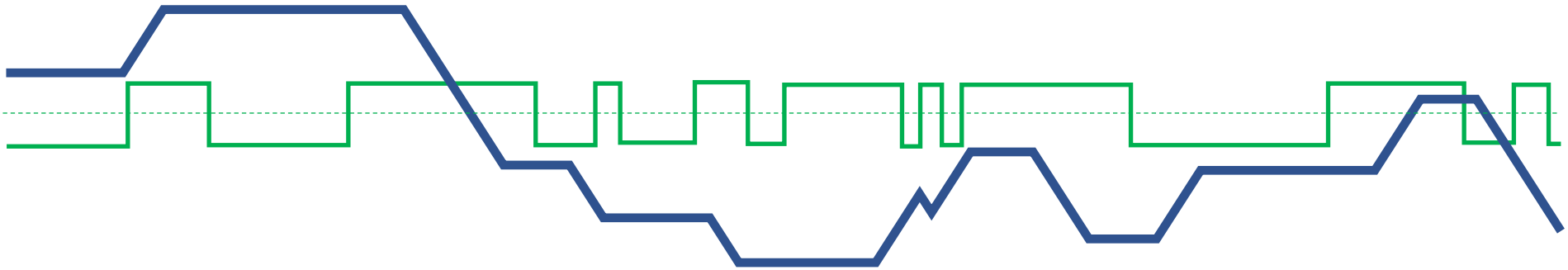
Adaptation

Practical Application

- Control remains ‘on’ even though performance may not be optimal
- Small PRBS perturbation is added – smaller than existing control moves
- PRBS iteratively updates a second model in the background

- Adaptive algorithm ‘knows’ how the plant with behave with current model
- Mismatch between expected and actual behaviour generates adaptive model

- Only need to adapt those paths that need to be changed
- Process knowledge is key



Cloud-Based Model Management

Real Time Manager Architecture

Features

- A common platform for development and real time systems
- Encrypted, version-controlled project storage and deployment
- Mapped with recipe / product tables

- Data extraction and modelling using **PerceptiveAPC Development**
- Manage **PerceptiveAPC Real-Time** instances for:
  - Deploying Chemometrics
  - Continuous Process Verification (CPV)
  - Statistical Process Control (SPC)
  - Advanced Process Monitoring, Control, Optimisation

  - OPC interface into process automation systems
  - User-friendly customisable secure remote displays
    - can be embedded into production systems

Cloud-Based Model Management

Real Time Manager Architecture

Model Updating / System Monitoring

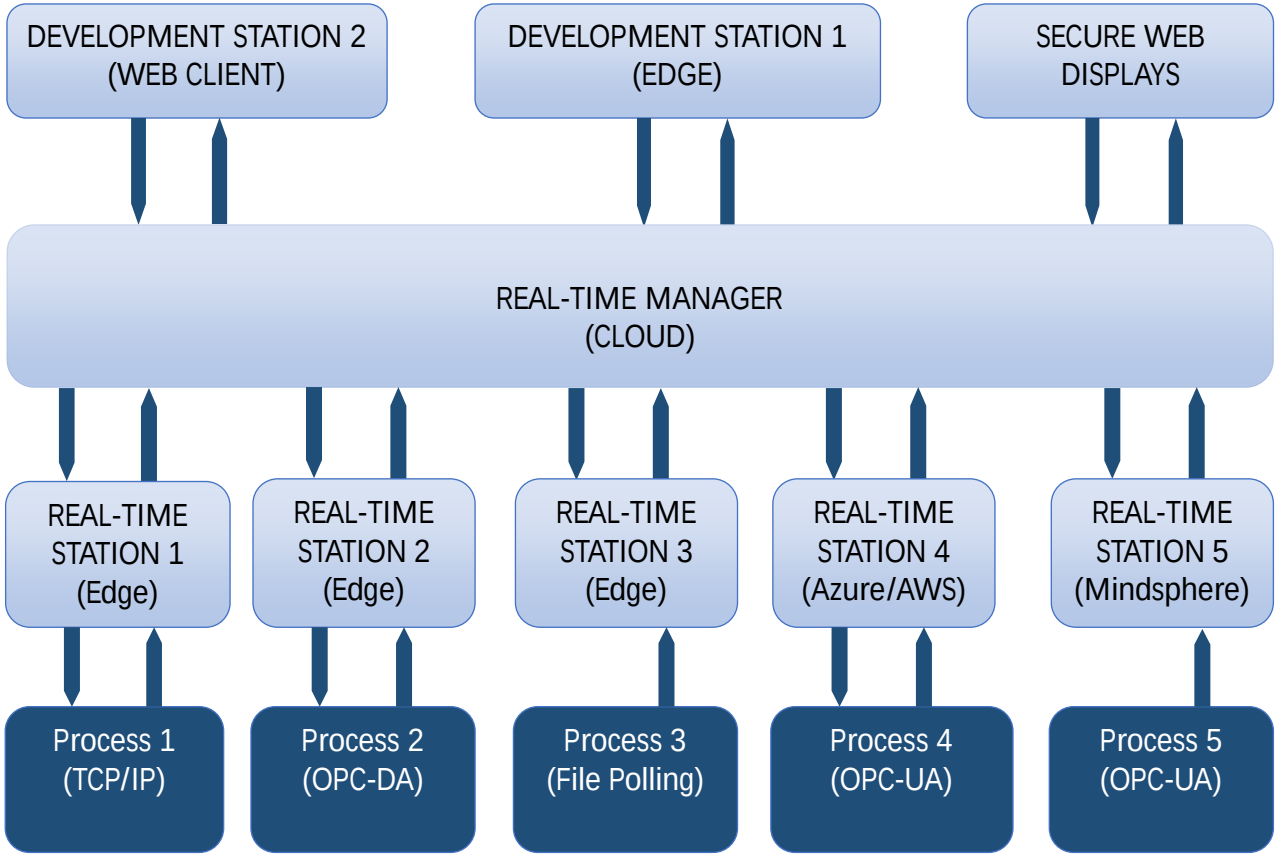
Model / Project Management

DQM

Multivariate Modelling

Ancillary Logic

Process



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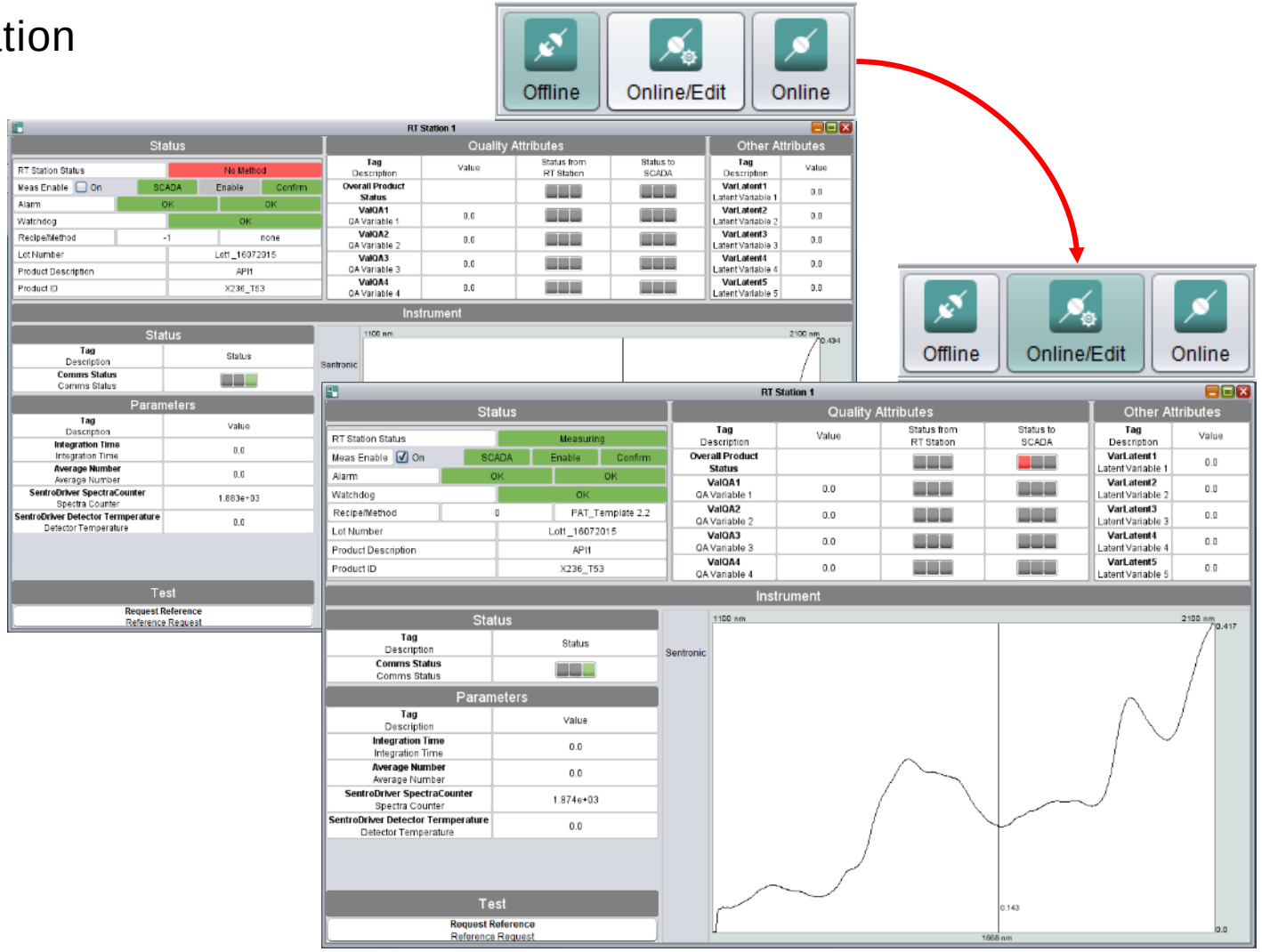
Dedicated Remote Interface for Each Station

Dissemination and Access

- Provide the **right** information
- To the **right** people
- **When** they need it
- Enabling full **interaction**



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In Practice

Manufacture of Personal Care Products

- Ingredients added, blended
- Batch tested, adjusted, blended, re-tested …. repeat until passed

Real Time Release

- Predict end quality from process, quality & raw material data
- Validate prediction against lab & at-line QC results before first trial

Project Results

- Initial goal 40% RTR
- 25 mins saved per 2-hour batch
- Increase in saleable production capacity equates to seven-figure financial benefit p.a.

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In Practice

Current Status

- Some CQAs difficult to measure – low repeatability
- Model predictions are trusted more than tested results
- Any discrepancy – repeat tests and take average of 5 results

Current Status - Manufacturing

- Adjust recipes, change ingredients
- Broader number of products adjusted to ‘fit’ the models – virtuous circle
- Now running at 100% real time release

Future

- Multi-site roll-out
- Cloud-based data capture, analytics, model selection

Summary

Big Data

- No-one really wants big data
- Manufacturers want ‘big knowledge’ and, from that, ‘big decisions’

With big data comes big responsibility

- Exponential increase in data
- Onus is on correct use of process models derived from that data
  - selection, validation, adaption and deployment
- Model management across distributed and disparate systems – what the cloud is for

Architecture

- AWS, Azure, MindSphere …. secure platforms for data collection and aggregation
- PerceptiveAPC – toolset for model development, validation, industrially-robust control
- Perceptive RT Manager – cloud-based management and model deployment

Thank you

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