Using the PI System to Support Prediction and Advanced Control of Reel-to-Reel Paper Quality

Presented by Tim Michaelson – International Paper
Chris McCready – MKS/Umetrics

INTERNATIONAL PAPER

UMETRICS
AN MKS COMPANY

International Paper

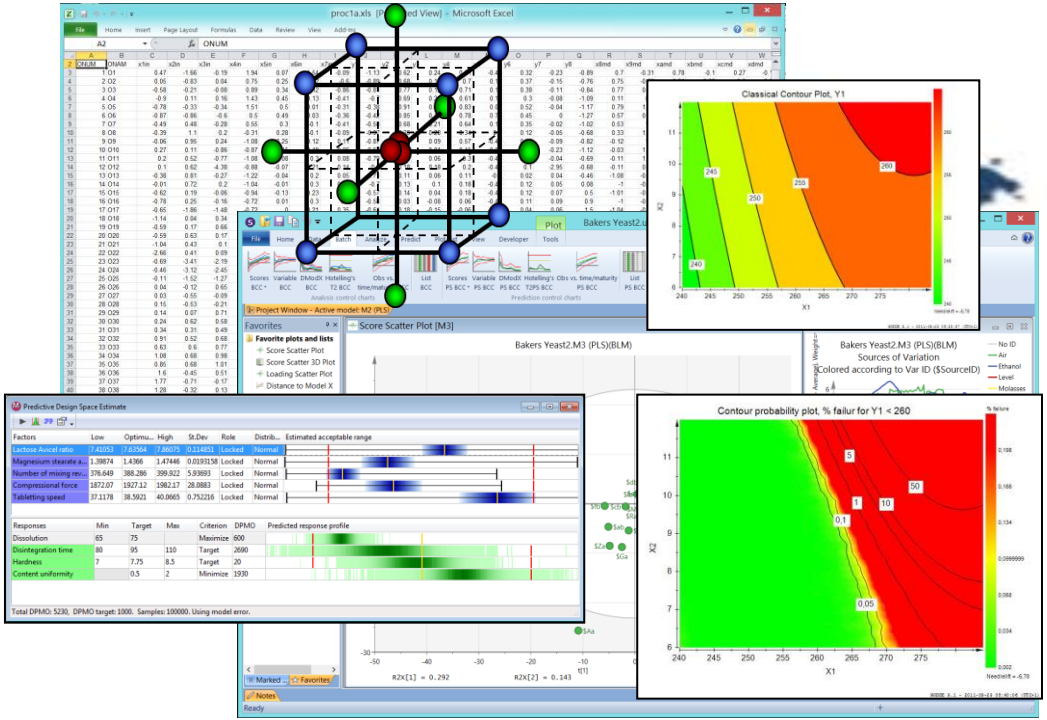
- World's Largest Pulp and Paper Company
  - Founded 1898 (117 Years Ago)
  - 58,000 Employees
  - $23.6 Billion Net Sales (2014)
- OSIsoft Installed Base
  - 35 Facilities (70 PI Servers)
    - US, Brazil, France, India, Poland, Russia
  - 1.5+ Million PI Tags

UMETRICS
AN MKS COMPANY

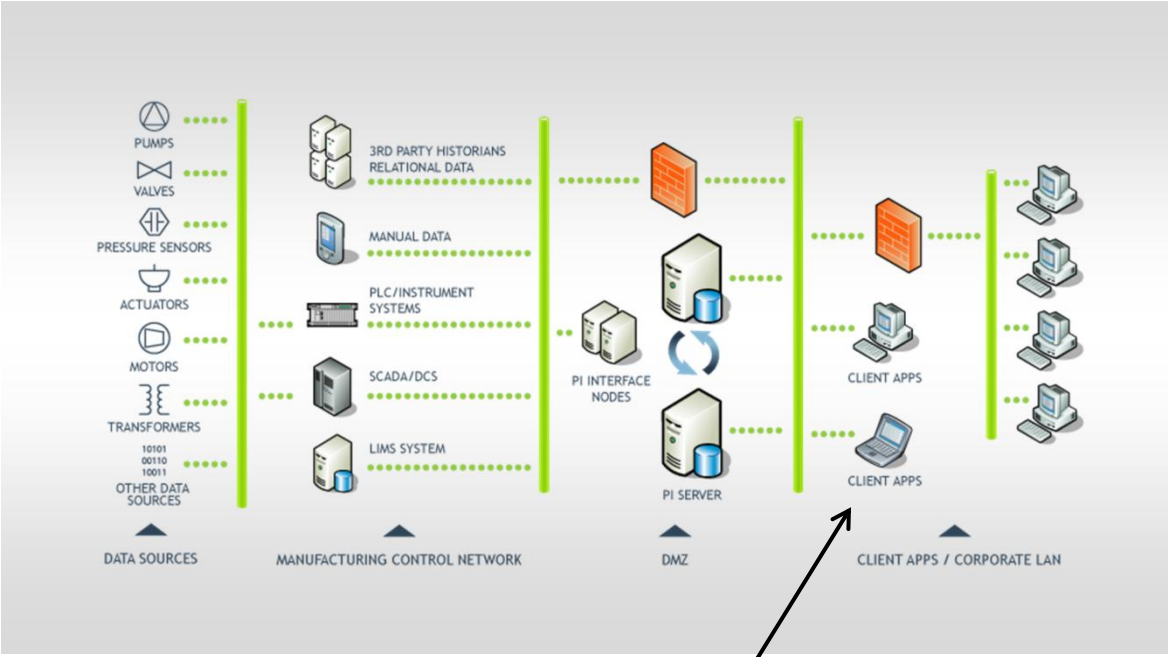
Value from Data

OSIsoft partner

- Design of Experiments (DoE)
  - Screening
  - Optimization
  - Robustness testing
- Multivariate Data Analysis (MVA)
  - Process characterization
  - Real-time process monitoring
  - Optimization and control
- Global Presence
  - MKS Instruments



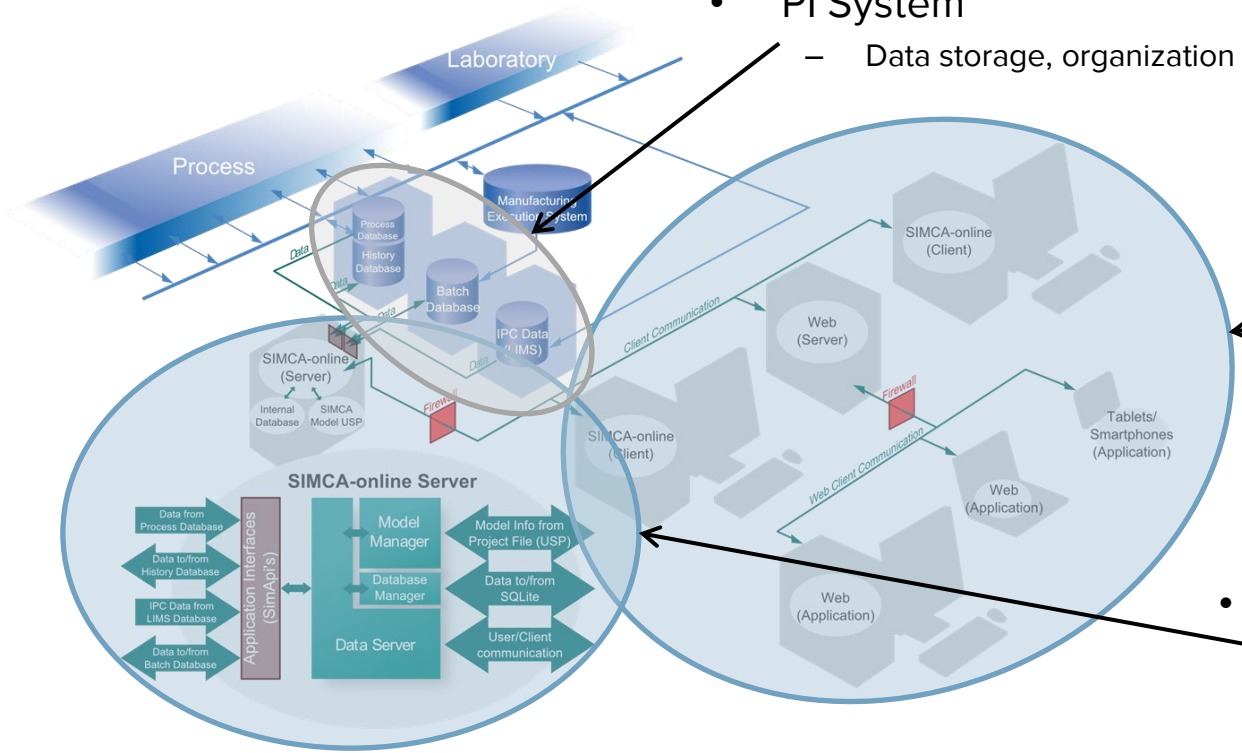
PI System Infrastructure in International Paper



SIMCA-online

- The PI System is used for storage, organization and retrieval of process data
- Umetrics' SIMCA and SIMCA-online are client Apps that perform multivariate data analysis

PI System Infrastructure at International Paper



- PI System
  - Data storage, organization and retrieval
- SIMCA-online Clients
  - Graphical user interface
- SIMCA-online Server
  - Data analysis, predictions and advanced control

The Challenge

- Quality(Smoothness)
  - Consistent feedback from customer
  - Recent (June 2013- June 2014) negative shift in smoothness levels that were not well understood
- The Opportunity
  - Leverage historical data and multivariate modeling methods to identify the key process variables related to a specific quality characteristic
  - Use a predictive model and develop a multivariate strategy for paper machine operators to maintain smoothness and properly act to control/reduce operational costs without negatively impacting quality

The Data (The Hard Way)

- Selectively extracted 1 year of operational data from PI Data Server at 1 min intervals for 600 reels of paper
  - Filtered for a single paper product made for a single customer
  - 1 year of data used to include seasonal variation and capture recent shift
  - ~250 process variables and 5-6 quality variables, including smoothness
- Used MVA batch modeling methods to focus on within-reel variation correlated to smoothness
  - Batch-wise unfolding and reel summary information
  - Narrowed down process variables to ~80 variables
  - Added calculated variables: Headbox Flow and Consistency, Total Refiners, etc.
  - Normalized many variables to throughput

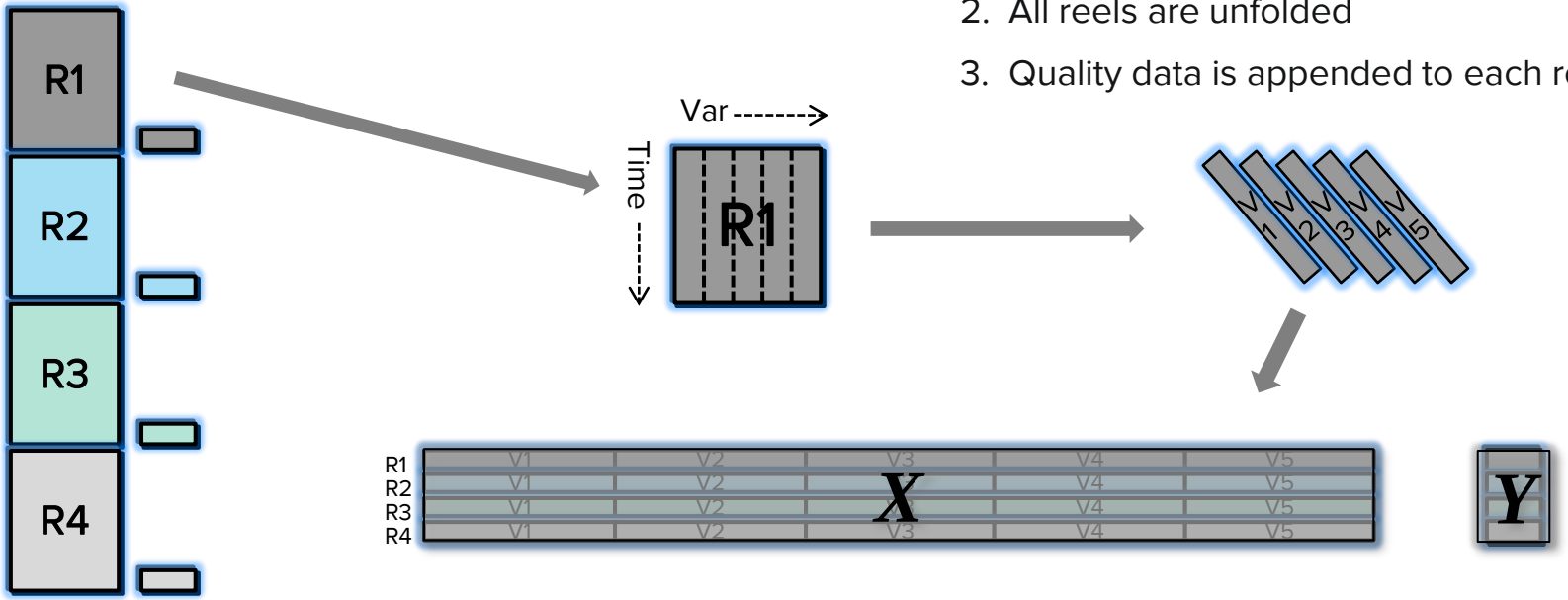
Data Transformation

Reel data has time dependency

- A table of data is generated for each reel
- Variables measured over time
- Quality is quantified at completion

Batch-Wise Unfolding

1. Each variable is transposed and aligned to make 1 row per reel
2. All reels are unfolded
3. Quality data is appended to each row

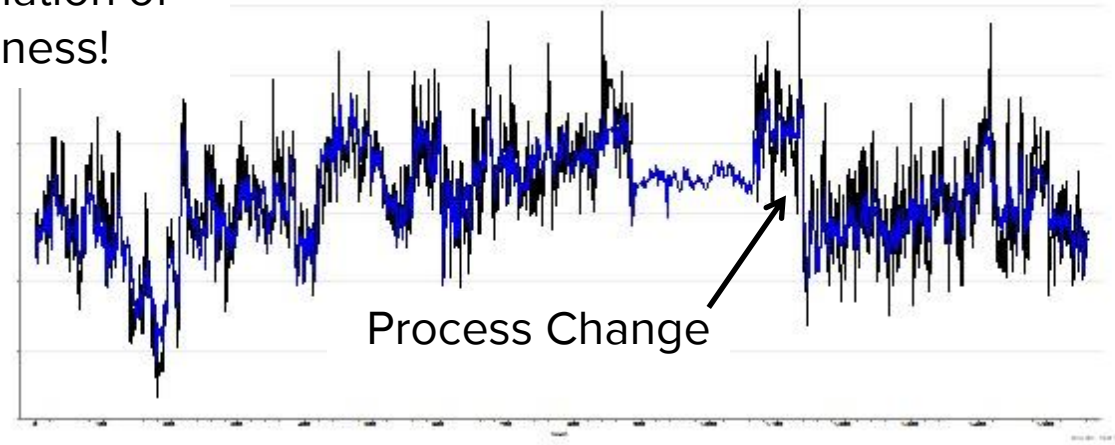


Development of a Predictive Model

- Measured and predicted smoothness
  - Measured (Black)
  - Predicted (Blue) – the smoothness is predicted based on the process measurements from the PI Server

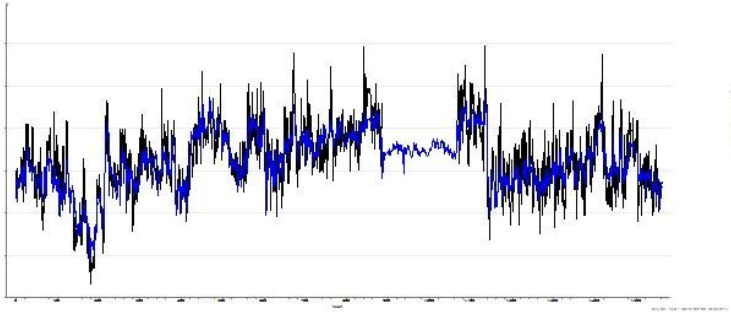
A very good explanation of variation in smoothness!

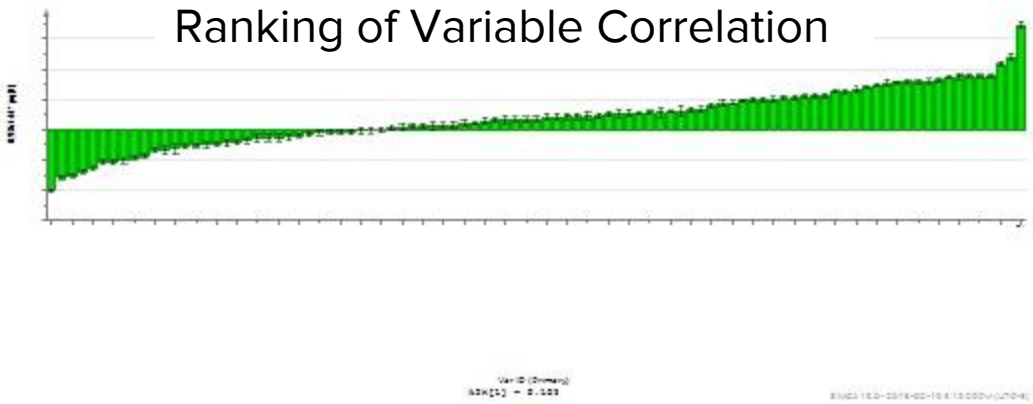
The model is tolerant to change in the process!



Building Process Understanding

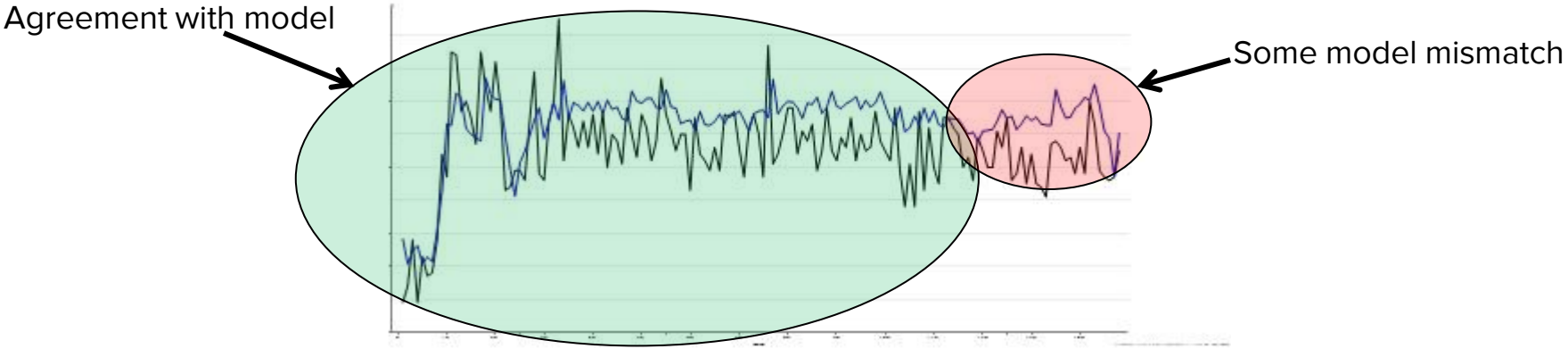
- PLS, a multivariate regression method, identifies process variables correlated to quality and performance
  - OPLS: further improves interpretation
  - Identify process variables that are highly correlated to quality





Model Verification

- In order to do control, model verification is needed to assure correlations are causal
  - Answers the question: can the model only be used for prediction or is it also useful for control?
- Verification bump tests were conducted
  - Verify quality is influenced as the model predicts



Improving Smoothness

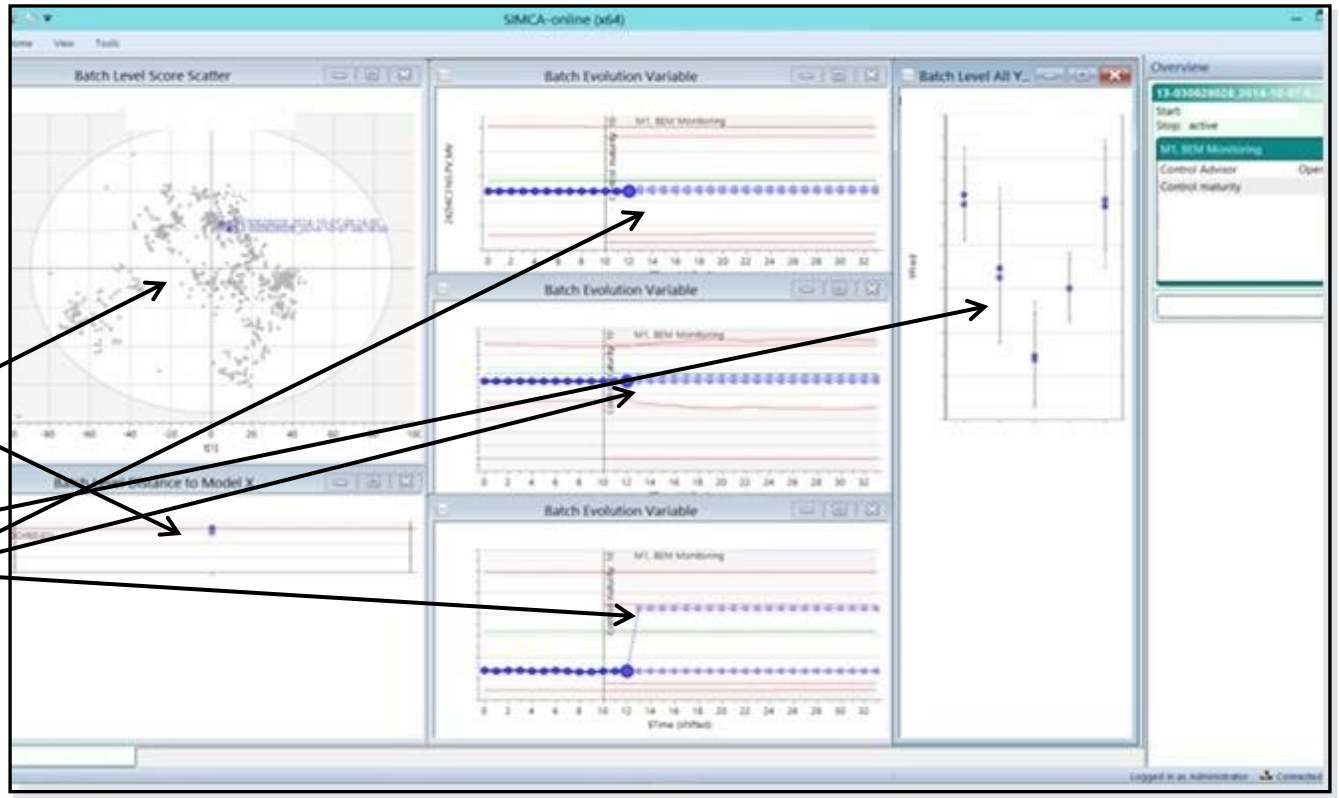
- A model predictive controller was built in SIMCA-online
  - Use the predictive model to estimate the impact of adjustments to the process on smoothness
  - Use optimization methods to search for the best set of process adjustments
- Seven key process variables were selected as variables the controller could adjust to improve smoothness
  - Based on knowledge, experience, and data

Controller Verification

- The controller is embedded within SIMCA-online

SIMCA-online provides

- monitoring of process conditions and health
- Prediction of paper quality
- Recommended paper machine settings

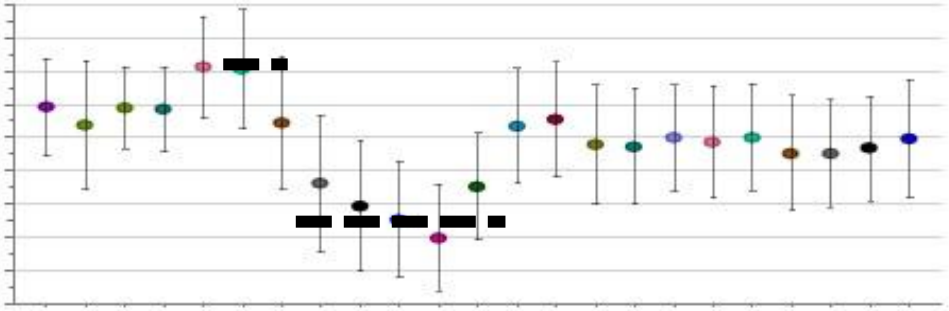


Paper Machine Performance Testing

- Use of the model to control smoothness
  - The model suggested adjustments to 5 process parameters
  - The adjustments were executed by the operators
    - Returned to the previous conditions after the process settled down

- The actual change in smoothness matched the prediction from SIMCA-online

Change in smoothness from a control move



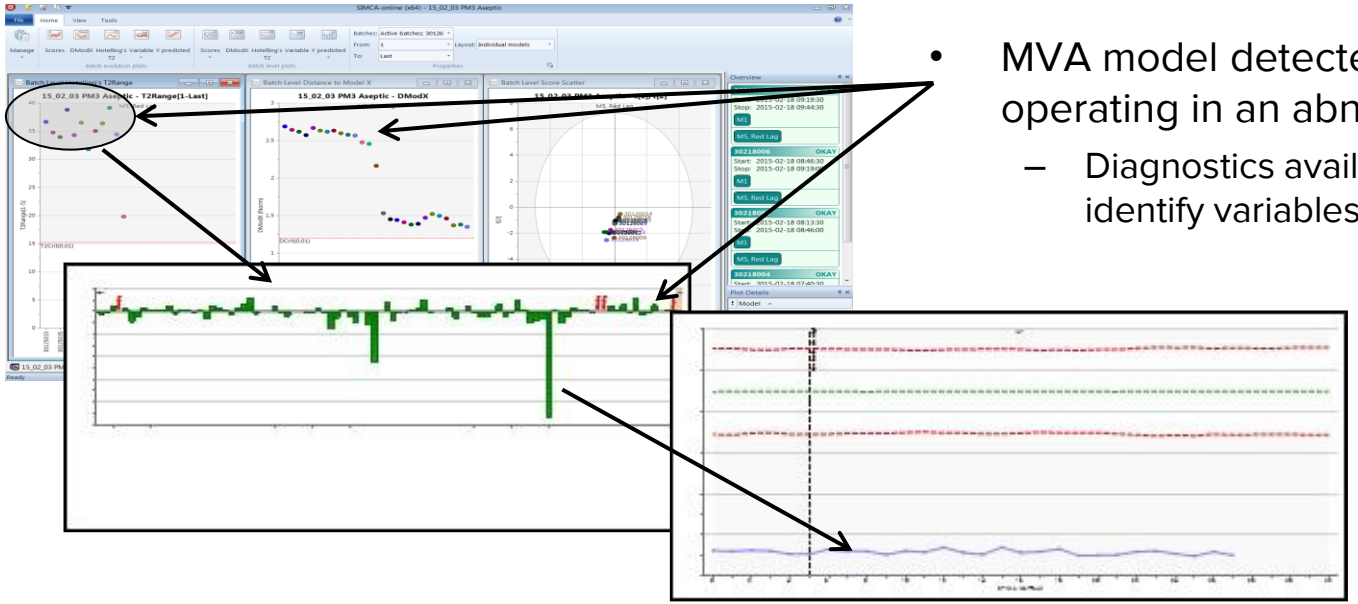
Value Generation

- Use multivariate optimization methods to maintain quality while reducing operational costs
  - Monitor/control multiple variables and multiple unit operations
  - Maintain smoothness and other quality metrics
  - Reduced operational costs and more efficient use of resources
- Provide a medium for Technology Subject Matter Experts (SME) to transfer knowledge to operations
  - A way to sustain improvements
- Leverage PI System data to provide operations a tool to identify and diagnose process performance in real-time
  - Summarizing a complex process with simple metrics
  - Create actionable information for operators

Intangible Benefit of Process Monitoring

Maximizing the Value of PI System Data

- Monitoring of Special Cause Variation
  - Example: Start-up of a paper machine

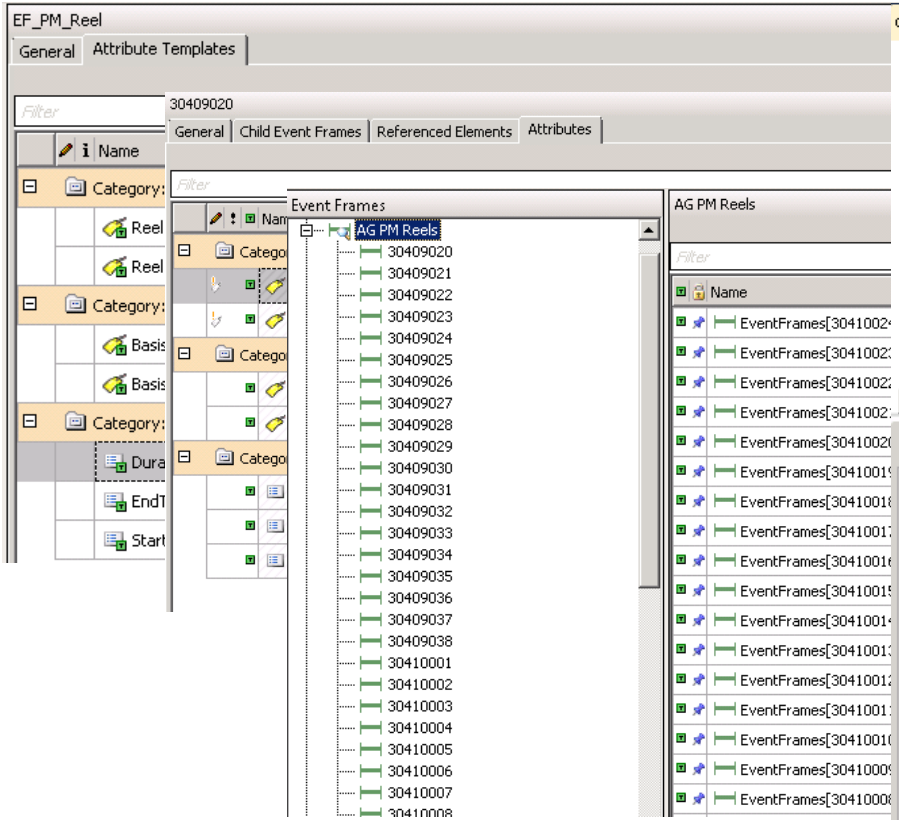


- MVA model detected the machine operating in an abnormal way
  - Diagnostics available in real-time to identify variables responsible

Opportunities

- Better Utilization of Advanced PI Server Functionality
  - Use of Event Frames/Asset Framework to reduce time and effort in future projects
    - Batching and visualizing the data
    - Filtering by paper mill, paper machine, customer, product
    - Native triggering of paper machine events (reel start, stop, & duration)
- Leveraging the Advances in Data Collection and Multivariate Techniques
  - Moving away from using historical PI System data (reactive) to utilizing real-time PI System data (proactive) to guide proper actions from operators
  - Treating paper reels as batches

The Data (The Easy Way)



qry_EF_PM_Reel_Augu....sql - Loveland Dev*

```
--****** Object: Custom Function TransposeEventFrameInterpolateRange_EF_PM_Reel Script I

SELECT ef.Name EventFrame, Time, tc.[Reel Speed], tc.[Basis Weight (Reel Scan)]
FROM
(
    -- Get first 100 event frames derived from EF_PM_Reel template
    SELECT TOP 1000 *
    FROM [Testing-Rick Smith].[EventFrame].[EventFrame]
    WHERE EventFrameTemplateID IN
    (
        SELECT ID
        FROM [Testing-Rick Smith].[EventFrame].[EventFrameTemplate]
        WHERE Name = 'EF_PM_Reel'
    )
) ef
```

Results | Messages

	EventFrame	Time	Reel Speed	Basis Weight (Reel Scan)
1	30409020	2015-04-09 16:06:00.000	1431.936	187.7405
2	30409020	2015-04-09 16:07:00.000	1431.937	188.7376
3	30409020	2015-04-09 16:08:00.000	1431.939	187.9217
4	30409020	2015-04-09 16:09:00.000	1431.944	188.7429
5	30409020	2015-04-09 16:10:00.000	1431.95	188.5617
6	30409020	2015-04-09 16:11:00.000	1431.956	188.3136
7	30409020	2015-04-09 16:12:00.000	1431.963	188.2312
8	30409020	2015-04-09 16:13:00.000	1431.969	188.2643
9	30409020	2015-04-09 16:14:00.000	1431.975	188.4428
10	30409020	2015-04-09 16:15:00.000	1431.994	188.426
11	30409020	2015-04-09 16:16:00.000	1432.024	187.8042
12	30409020	2015-04-09 16:17:00.000	1432.054	188.9403
13	30409020	2015-04-09 16:18:00.000	1432.083	188.1428

Conclusions / Words of Wisdom

- Build advanced Model Predictive Control (MPC) on historical data, then leverage real-time data
  - Batch unfolding techniques with multivariate modeling methods
- PI System is the key to data collection and organization
  - Utilize Event Frames to reduce time and effort in data collection
- Don’t forget the three-legged stool when solving complex issues
  - Knowledge, Experience, and Data!!

Questions

Please wait for the microphone before asking your questions

State your
name & company

Tim Michaelson

Senior Manufacturing Excellence Consultant

INTERNATIONAL PAPER

- www.ipaper.com
- +1.901.412.5491
- tim.michaelson@ipaper.com

Chris McCready

Principal Engineer

UMETRICS
AN MKS COMPANY

- www.umetrics.com
- +1.973.879.2514
- chris.mccready@umetrics.com

THANK YOU