Digitalisation and Transformation of Process Analysis

Sundeep Saraf
VP Global Sales - Analytical
Yokogawa Electric International

Marcus Trygstad
Consultant, Advanced Analytical Solutions
Yokogawa Corporation of America

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AGENDA

- History and where are we heading with Digitalization
  Industrie 4.0
- Transformation of Process Analysis to Process Monitoring for Control ***PM 4.0***
- Analyzer-enabled Integrated Solutions
- Technology Fusion – IIoT
  Hard/Soft Analyzers

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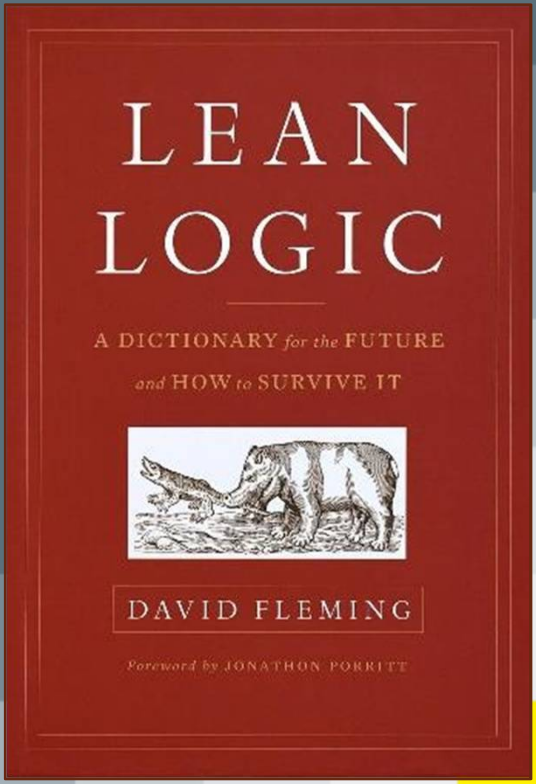
“Forward movement is not helpful if what is needed is a change of direction.”

— David Fleming

Lean Logic: A Dictionary for the Future and How to Survive It



Living Through Shifting Paradigms… i4.0

Paradigm Shifting…

from Process Analysis

to Process Monitoring for Control

Q1: What's the difference?

– Isn't process analysis for process control?

Q2: Why shift the paradigm?

– Isn't the current one working just fine?

Process Analytics Today (a 50 year old paradigm)

System Integration (Engineering and Packaging)

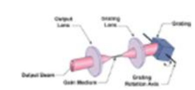
Process Analytics focuses on the process analytical enterprise

Sample Systems

(Process Application Expertise)

The Stream Data Sheet is the principal vehicle for engagement

3rd Party Analyser Partners



New Technology Partners

Analytical Products (Science & Engineering)

Is Process GC here to stay ?

Advantages historically

- Highly versatile & configurable
- Relatively low initial cost; ongoing cost of ownership acceptable
- Vendors and users enjoy economies of scale and "sameness"

GC versatility and ubiquity unlikely to ever be repeated

- Yet, sustainability is a growing concern amongst operating companies
- **Spectroscopic technology is catching up fast**

"Delivering" Analysis	GC	Spectroscopy
Hardware Design	Straightforward	Evolving
Production	Straightforward	Straightforward
Application configurability	Established	Developing
Calibration/Tuning	On site	Upfront
Maintenance	High but Manageable	Low

Industrial Revolutions

Industrie 2.0

Industrie 3.0

Industrie 4.0

Process Monitoring

PM 2.0

PM 3.0

PM 4.0

Conceptual Vocabulary is needed to drive future technology discussions

But First… How did we get here?

How did we get here?

Era	Industrie 2.0	––– Industrie 3.0 –––	
Description	Pre-Automation	Early Automation	Mature Automation
Decade	Before 1970	1970s	1980s forward
Sampling, Analysis	Manual, Lab	Online	Online
Process Control	Adjustment by Operators	Adjustment by Operators	Closed Loop
Data Reporting	Manual or automatic input into a LIMS Transmitted to DCS		Direct output to the DCS
Increasing Control Resolution (CR)	→	→	→

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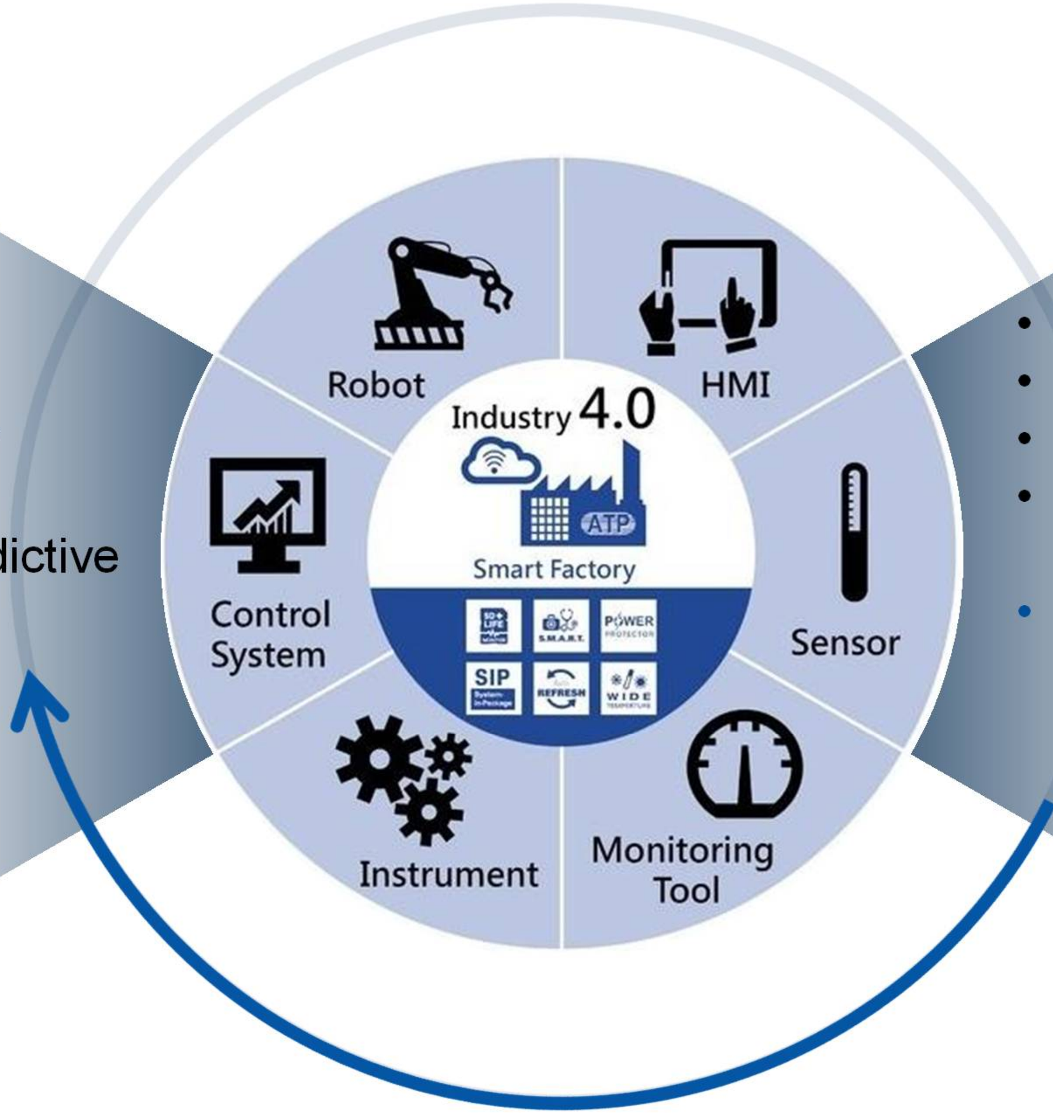
PM 4.0 Integrates Monitoring into Control

- DCS
- Regulatory Control
- Model Predictive Control
- Inferential Analysis



- Pressure
- Temperature
- Flow
- Physical Properties
- **Chemical composition using PM 3.5 technologies**

History of Analyzers till PM 3.0

Adapted-Type

Inception: Automation of Laboratory Instruments

- Gas chromatographs
- NIR spectrometers
  - FT- and dispersive
- Mass spectrometers
- Hot/Cold Property Analyzers
  - Reid Vapor Pressure
  - Cloud Point
  - Cold Filter Plug Point
- Elemental analyzers
- Anti-knock index analyzers
- pH, ion-selective electrodes

Purpose built -Type

Conceived and Purpose-Built for Online Implementation

- Infrared and UV-Vis photometers
- Zirconium oxide sensors (O_2)
  Moisture Sensors
  - Aluminum oxide
  - Vibrating quartz crystal

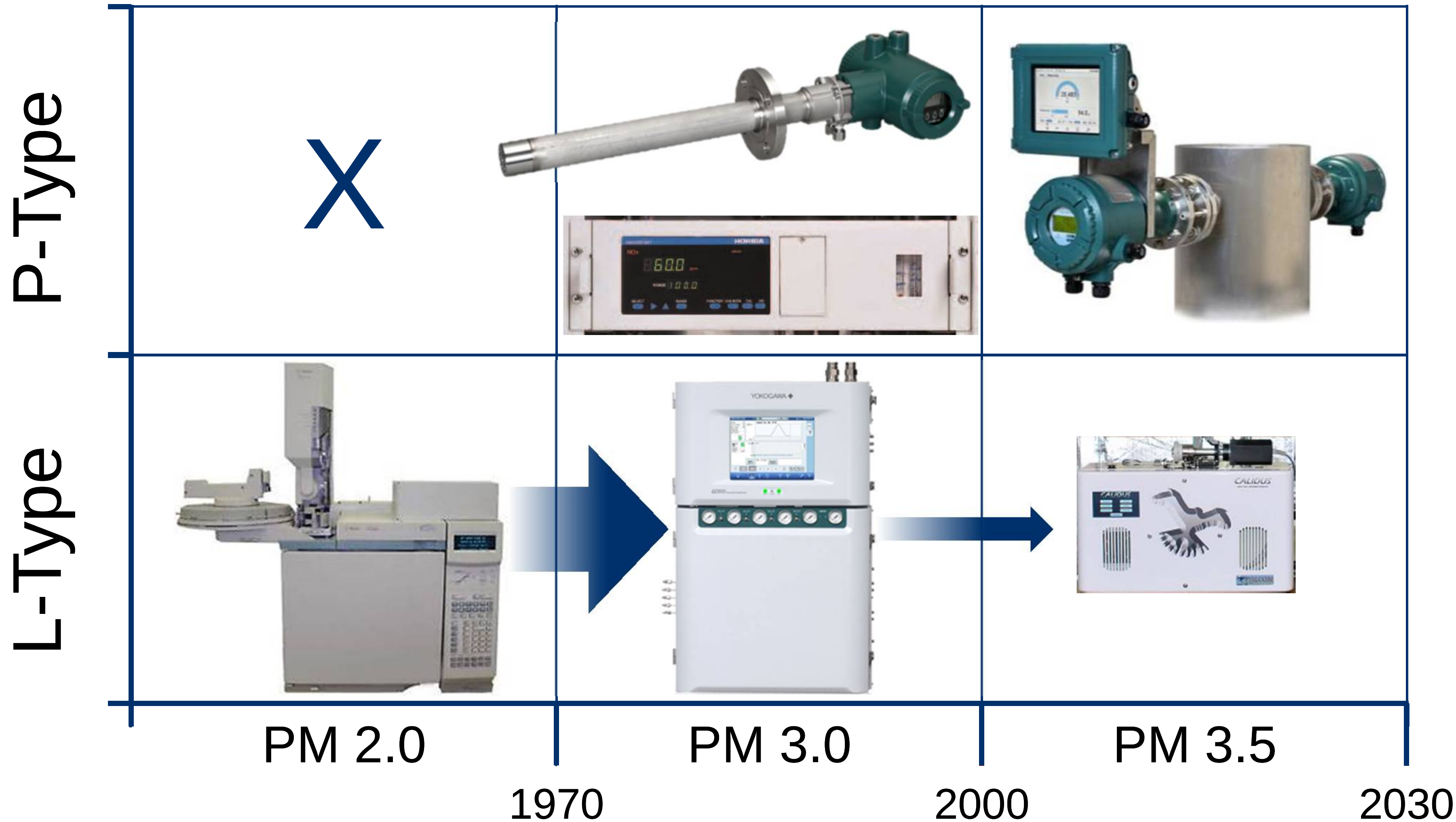
The PM "Decoder Ring"

PM 2.0, PM 3.0	Concern: analysis, analyzers, and their operation
PM 4.0	Concern: control/optimization, economic realization
PM 3.5	Concern: support of and compliance with PM 4.0

PM 3.5 Scorecard

- ☑ Analysis rate high vs process
- ☑ Permanently Calibrated
- ☑ App-Based Operation
- ☑ Auto/Remote Diagnostics
- ☑ Low Maintenance
- ☑ Pipe-centric (online)
- ☑ "Self-Aware" (Self-Validating)
- ☑ App-Based Monitoring
- ☑ Smart Sampling
- ☑ "Fit and Forget"
- ☑ An integrated element of the process control system (incl. safety)
- ☑ Part of a multivariate sensor system

Analyzers in PM 2.0, PM 3.0, and PM 3.5

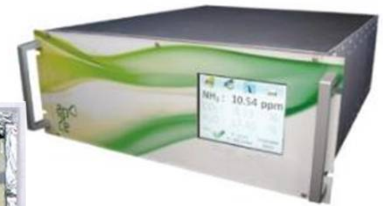


Some Examples of PM 3.5

H_2O and CO_2 in Natural Gas by TDL

QCL for Gas Analysis

Fast GC



OFCEAS for Trace Gases

Process Raman for Liquids and Gases

ICOS for Trace Gases

Combustion Monitoring by TDLS

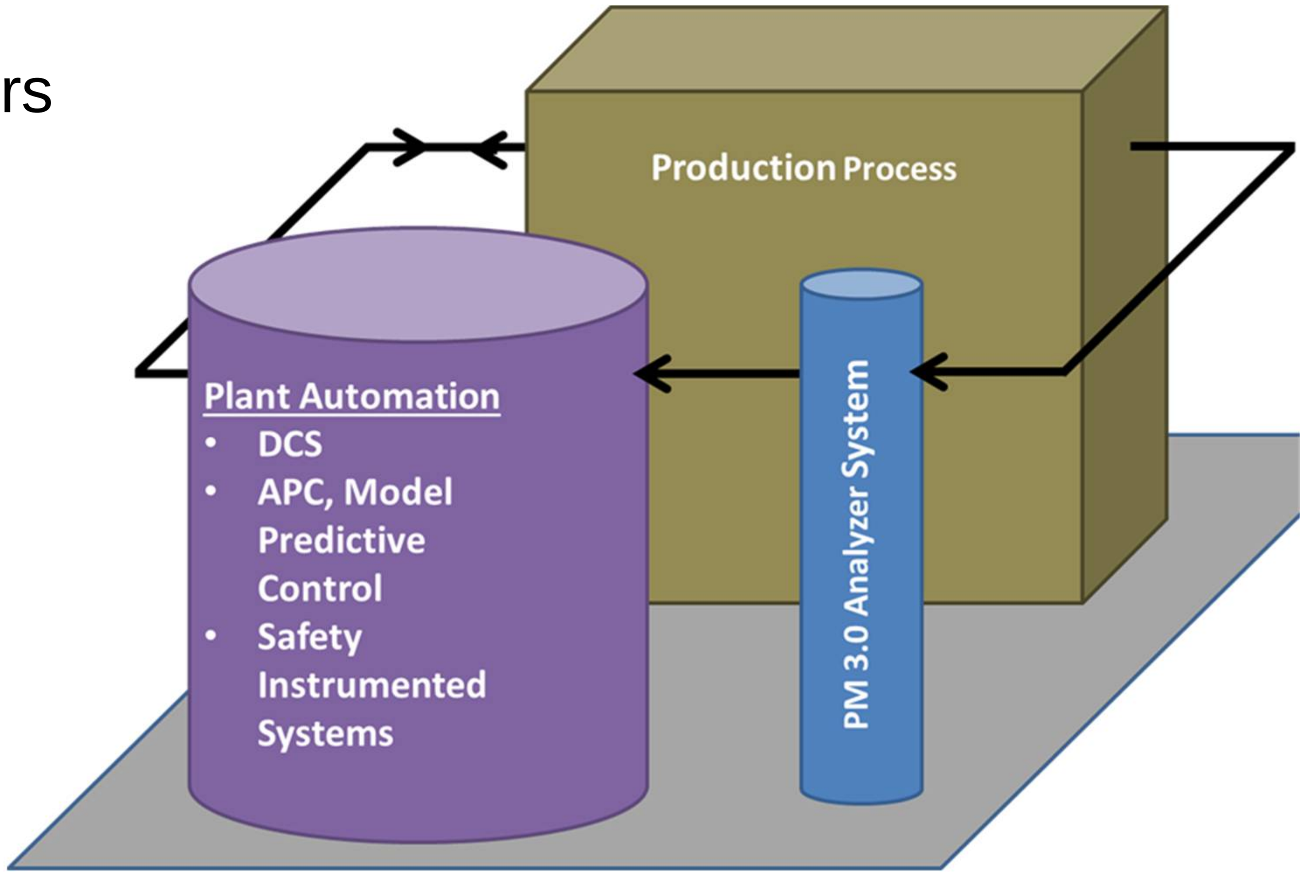
Fabry-Pérot Interferometry for Bulk Composition

To varying degrees, these technologies are supporting the trend away from shelter-centric deployment

Industrie 3.0 and the existing PM 3.0 Paradigm

- Automation and analytical technologies are connected but siloed

- Interface Analyzers to the process, then output results to the automation system

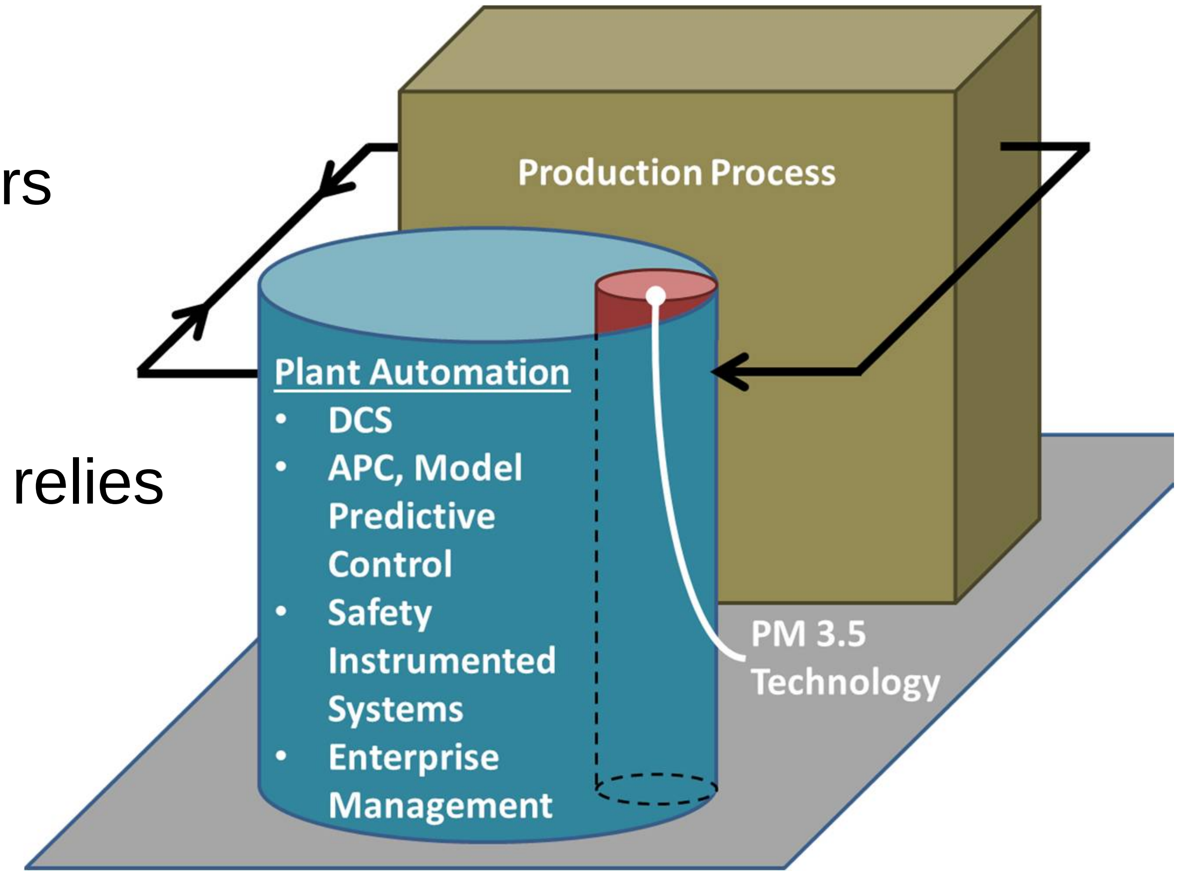


Industrie 4.0 and the New PM 4.0 Paradigm

- Analytical technology is an element of a digitally integrated manufacturing system

- PM 4.0 is not Analyzers

- Realization of PM 4.0 relies on PM 3.5 analytical technologies that are PM 4.0-compliant



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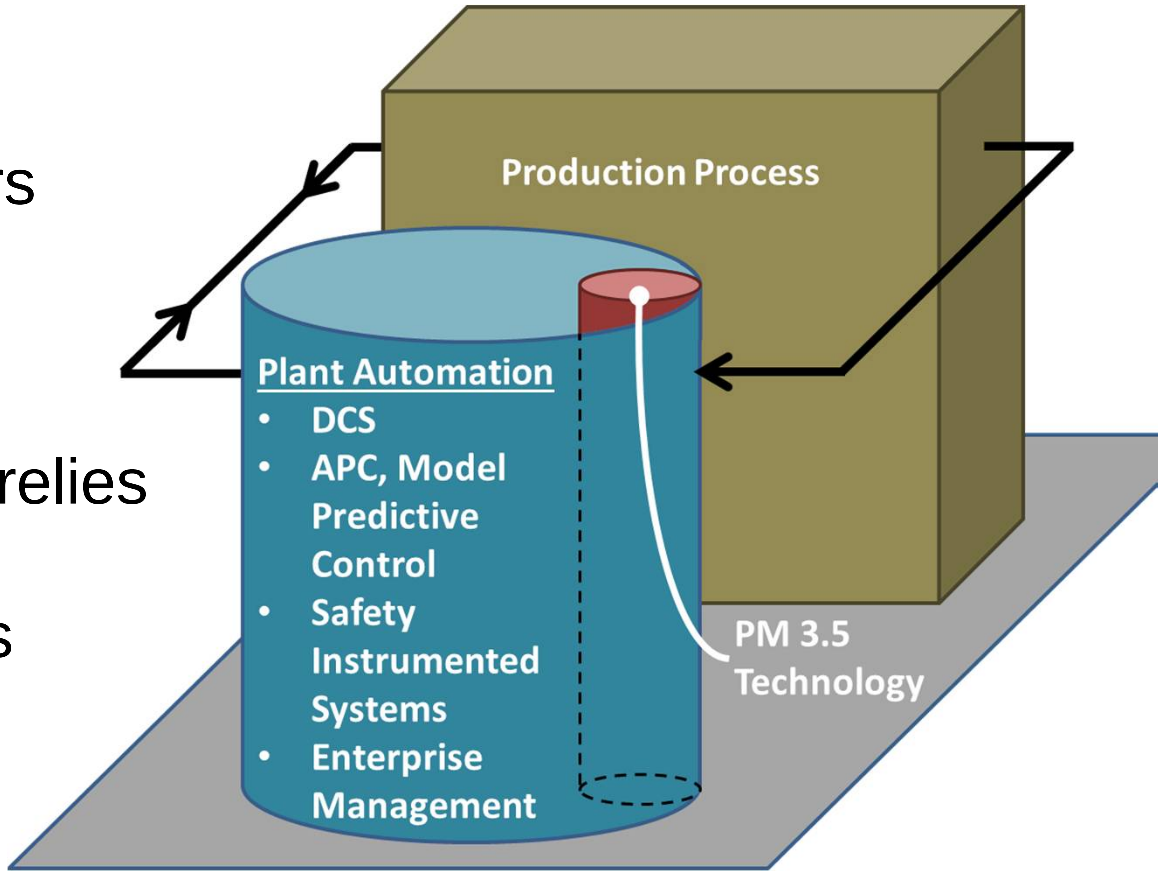

Industry Trends that will define PM 4.0

PM 2.0 → PM 3.0 → PM 4.0

Intertwined issues: Knowledge, Technology, and Economics	K	T	E
Increasing variety and sophistication of Analytical technology	X	X	
Increasing numbers of measurement points for Analysis	X		X
Demographic Shift in Core Process and Analyzer Knowledge	X		X
Increasing pressure Capex costs			X
Increasing focus on Analyzer availability	X	X	X
Increasing expectation to "fit and forget" type instruments	X	X	X
Increasing dependence on vendor expertise	X	X	X
Increasing motivation to explore Inferential based solutions		X	X

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Characteristics of PM 4.0

INCREASED MEASUREMENT RESOLUTION → INCREASED CR

- Increased number of measurements per stream per unit time
- Increased measurement precision (sensitivity to composition changes)
- These enable increased **C**ontrol **R**esolution

MEASUREMENTS ARE INTEGRATED WITH OTHER DATA

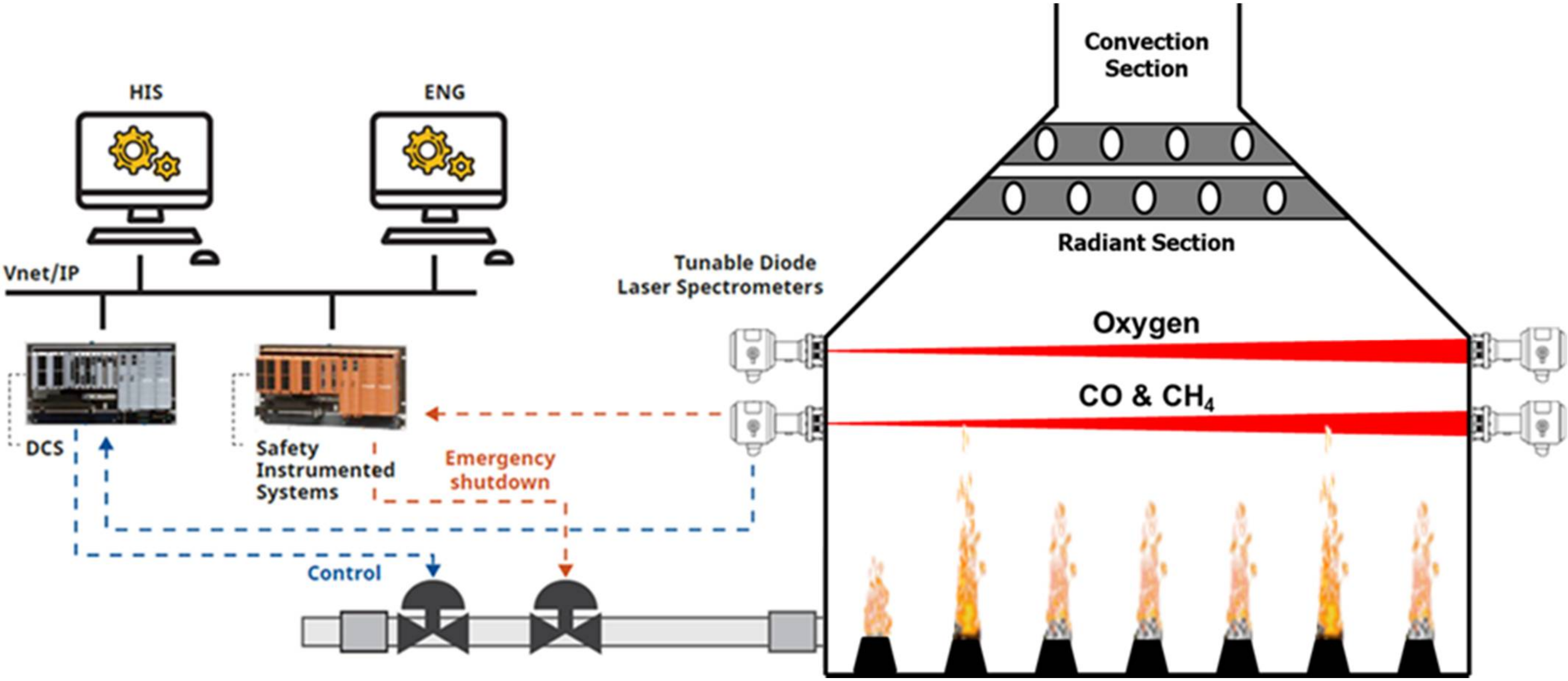
- Analytical measurements are not regarded individually (discretely)
- Reduces overall control uncertainty

ANALYSIS IS INTEGRATED WITH CONTROL

- System conceived as a whole (analyzers not merely an addition)
- The whole >Σ(parts)
- Analyzers are integral to the control / safety / compliance strategy

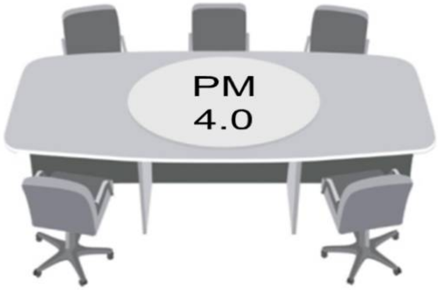
An Example of PM 4.0 in Action Today

Furnace Optimization and Safety Systems



Comprehensive Solution based on Technology Fusion

PM 4.0 – Drives Convergence of Goals



Technology fusion brings diverse stakeholder concerns to a common table

Stakeholder	Concern	Typical Solution
Ops Mgr	Throughput Efficiency	New Burners, New Tubes, Convection Section
Energy Mgr, Ops Mgr	Fuel Efficiency	One Time Manual Tuning
HSE, Reliability	Safety	Burner Mgmt System, Flame Scanners
HSE	Emissions	SCR*, Low NO_x Burners
Engineering Mgr, Reliability	Asset Sustainability	Scheduled Preventative Maintenance

* Selective Catalytic Reduction

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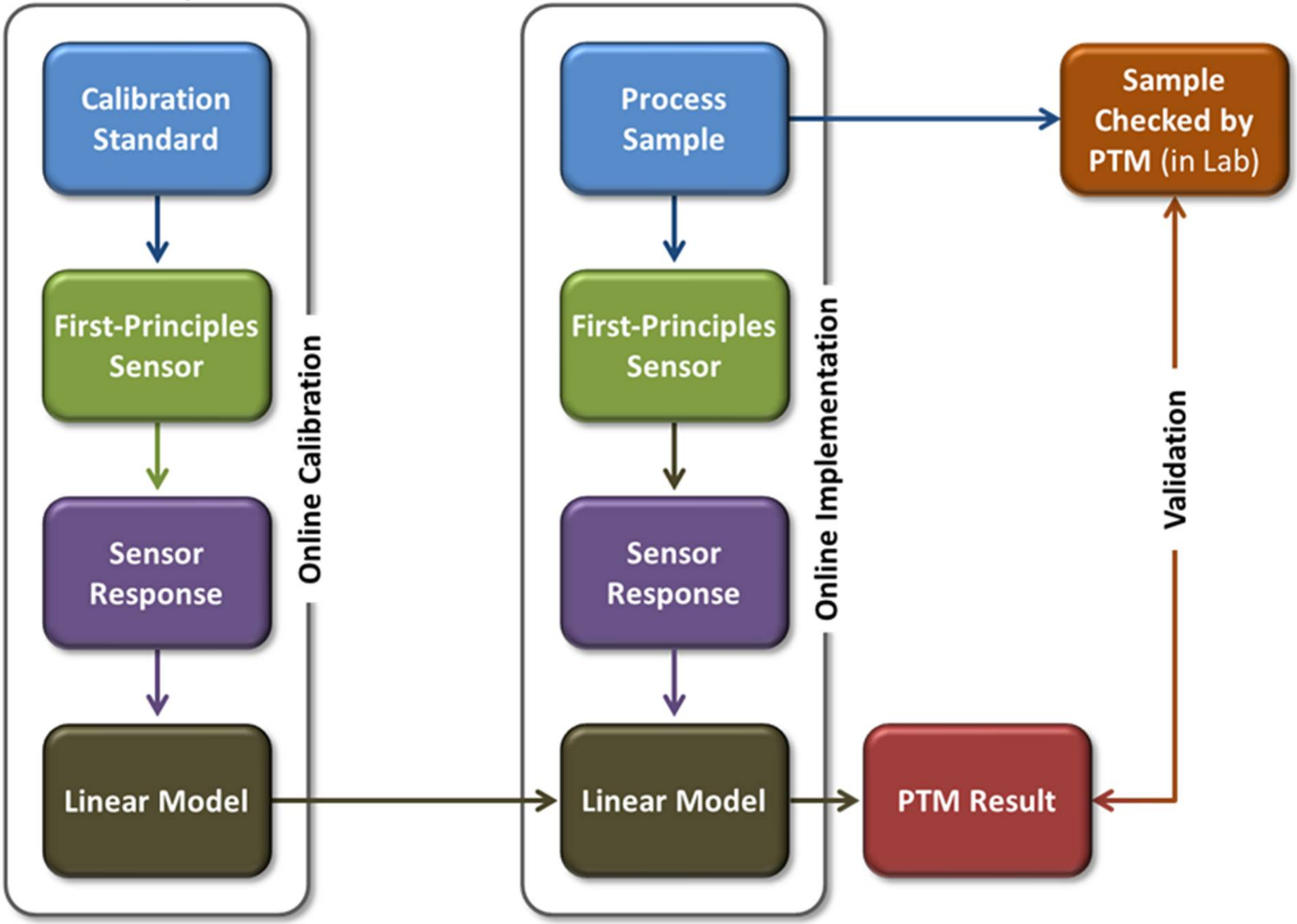
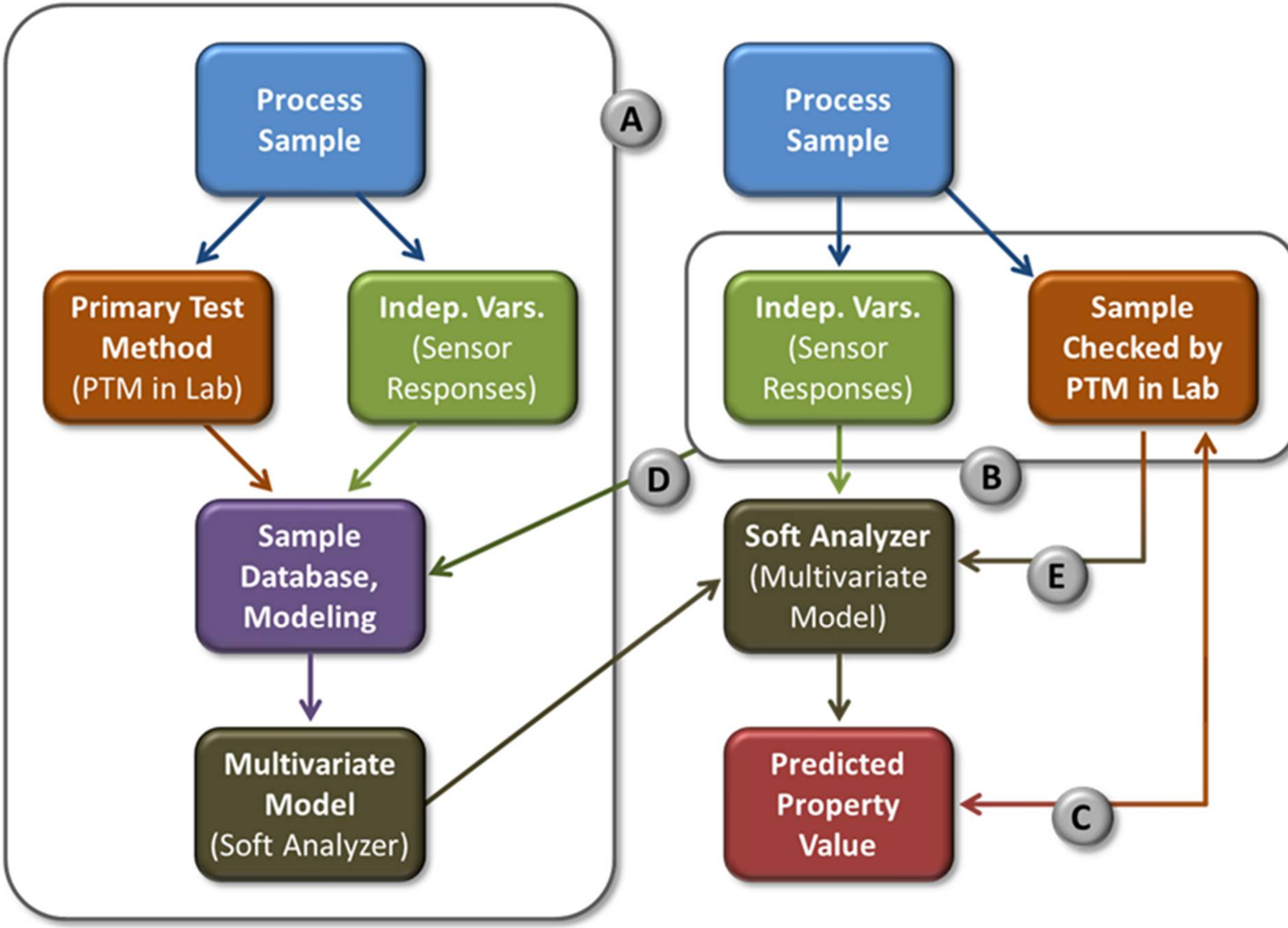
Hard Analyzers – Operational Model

"Hard" Analyzers **Measure** (actual sample used , based on first principles)



Soft Analyzers – Operational Model

"Soft" Analyzers **Predict** (use multivariate statistical correlations)



Hard vs Soft Analyzers

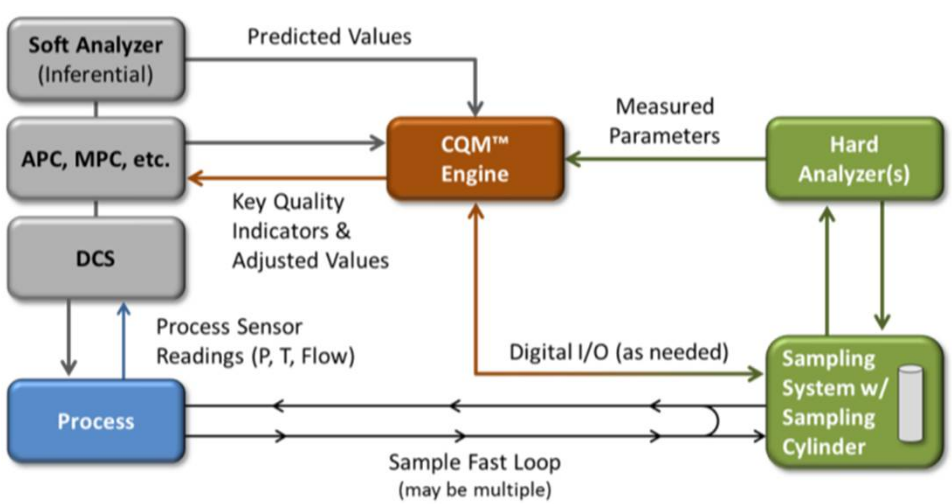
Hard Analyzers	Soft Analyzers
First-Principles, discrete, univariate, ASTM Sanction	Referenced, multivariate, based on data arrays
“Hard” Correlations relate directly to sensor response	“Soft” Correlations (models) are the analyzer, operating on the array
Actual Measurements	Statistical Predictions
Measurement basis well understood, rooted in science	Basis of correlation often not clearly understood
Known to work due to first principles	Correlation is “proof” that “it works”
Calibration based on a few samples	Calibration is population-based
Few measurement per analyzer	One array, many analyzers (models)
Measurement frequency limitations	Substantially Instantaneous
Capital- and maintenance intensive	“Free” (cost to build data set)
Robust across wide range of values	Calibrations generally not robust

Technology Fusion (examples)

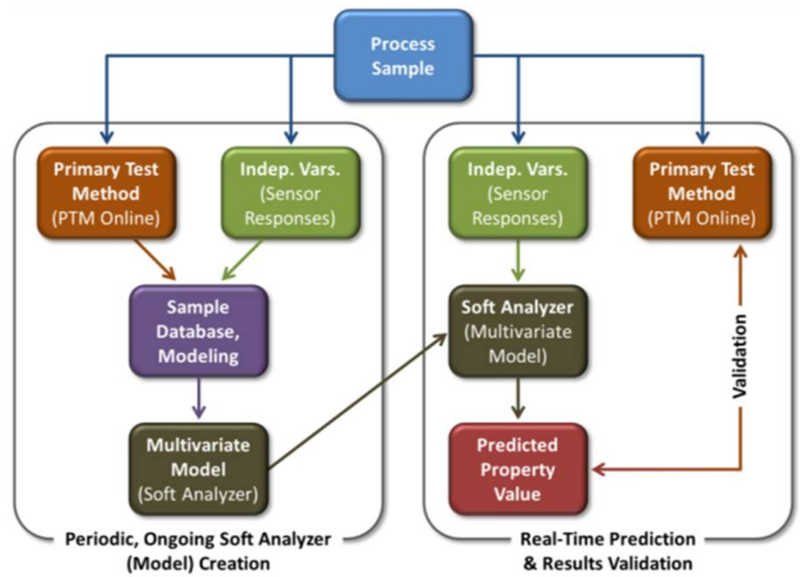
Yokogawa awarded patents for both in 2018

Cognitive Quality Manager for Monitoring and Optimisation

Crude Rundown Streams



RVP in Gasoline Blending



Technology Fusion: Beyond the Best of Both

Leverages advantages, mitigates weaknesses of hard and soft analyzers

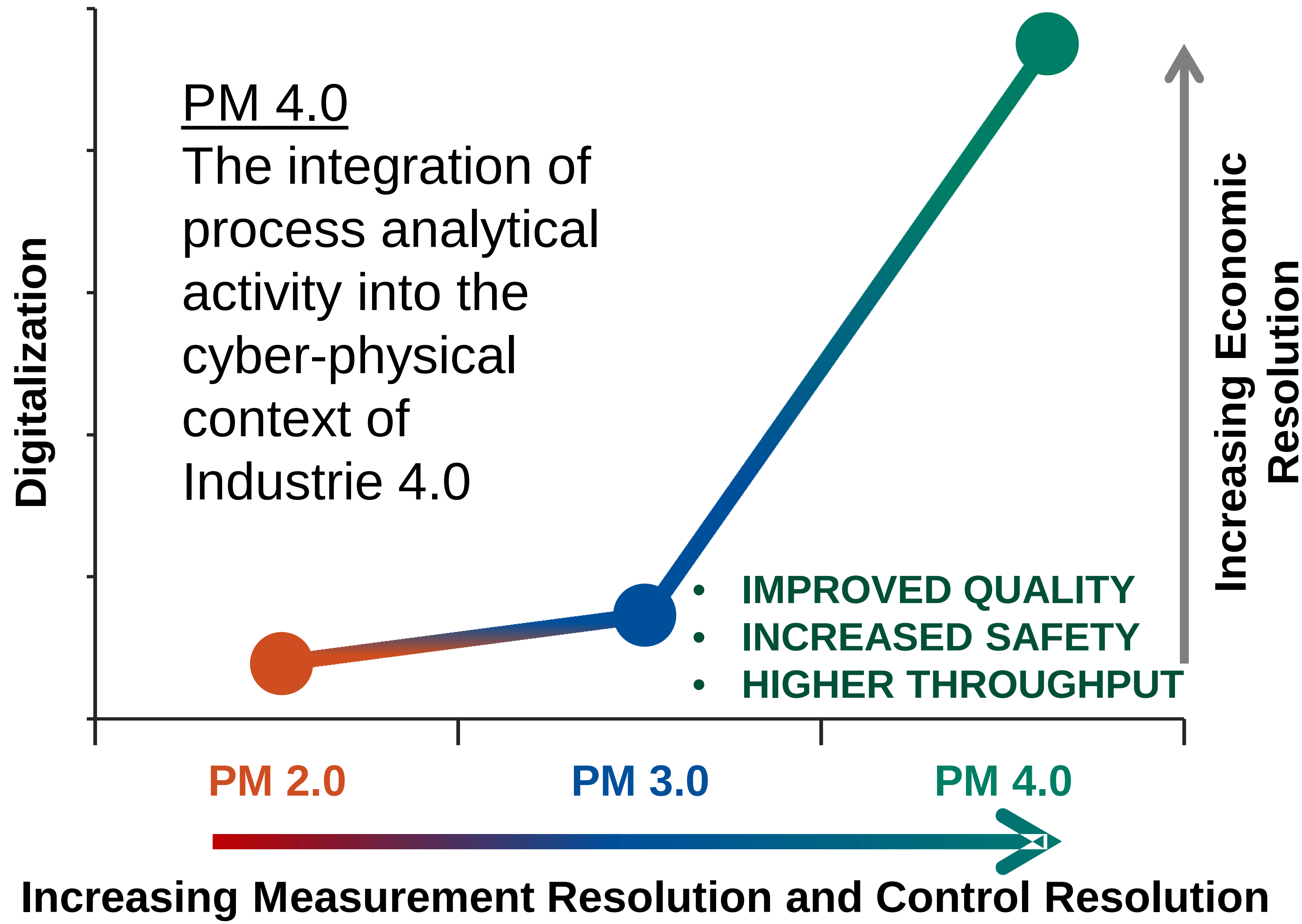
- The speed and adaptability of inferentials
- The “realness” of hard analyzers

- Other non-intuitive benefits
- Not merely “doubling-up” or redundancy

- Exploits the power of regression statistics to “filter” noise (imprecisions) in all variables
- Reduces measurement uncertainty* by >80% vs ASTM reproducibility (hard analyzer method)

* Trygstad, Marcus; Pell, Randy; Roberto, Michael, “Motor Fuel Property Prediction by Inferential Spectrometry 2: Overcoming Limitations”, Proceedings of the ISA 60th Analysis Division Symposium, AD.15.04.02, Galveston, Texas, April 26 – 30, 2015.

The Future of Process Monitoring: PM 4.0



Thank you very much