THE REYNOLDS COMPANY
ELECTRICAL SUPPLY

User Group

Machine Learning and AI for Industrial Applications

April 14, 2021

Our Guest Panelists

Niraj Kachadia

Rockwell Automation
Architecture & Software
Business Lead

Mike Masterson
Wayne Welk
Brian Mikeska

The Reynolds Company
Automation Specialists

2021 Online Events

Register to receive a calendar invite

THE REYNOLDS COMPANY
ELECTRICAL SUPPLY

TechTalks

- **WIN911 Alarm Notifications for Industry and IIoT**

  Wed, Apr 21, 2021 @ 10am

- **CIP Safety over Ethernet/IP**

  Wed, May 12, 2021 @ 10am

- **PowerFlex Drives Integration with Fisher ROC**

  Wed, May 26, 2021 @ 10am

User Groups

- **Machine Safety vs Process Safety - SIL vs PLe**

  Wed, May 19, 2021 @ 10am

reynoldsonline.com

2021 PTC LiveWorx
Online

THE REYNOLDS COMPANY
ELECTRICAL SUPPLY

LIVEWORX 21™
THE LIMITED SERIES

Episode One: Work Methods Changing the Workplace

Thurs, March 25 – Now on Demand

Episode Two: The New Frontier of Product Development

Thurs, Apr 22, 2021 @ 9 am CST

Episode Three: Digital Transforms Physical

Thurs, June 24, 2021 @ 9 am CST

PTC Global Partner Summit

Tues, June 15, 2021

ANALYTICS

The ***discovery***, ***interpretation***, and ***communication*** of meaningful patterns in data. Analytics relies on the application of statistics, computer programming and operations research to quantify performance.

"I want someone delivering Analytics who was in a plant last week, last month and last year and not someone who was making video games recently."

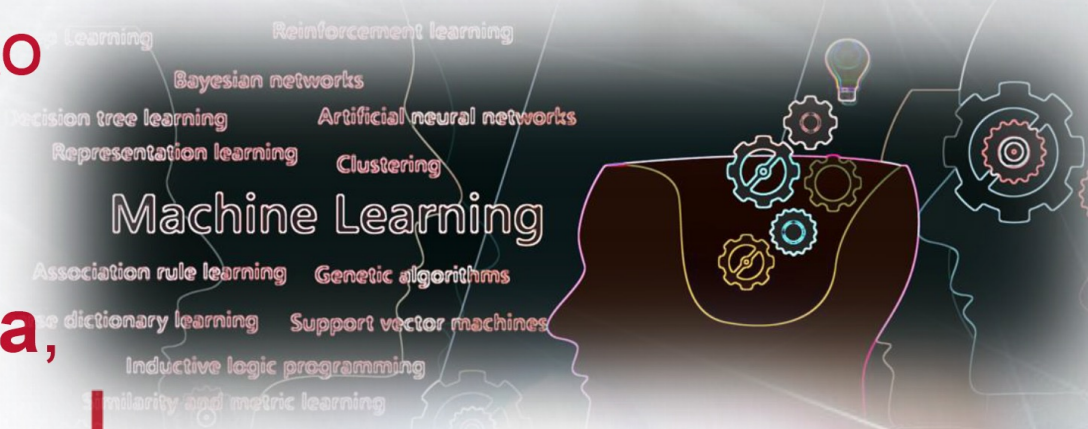
— A Rockwell Automation Customer

Rockwell Automation

Machine Learning 101

Machine learning is a field of computer science that uses statistical techniques to give computer systems the ability to **"learn"** (i.e., progressively improve performance on a specific task) **with data**, without being explicitly programmed.

https://en.wikipedia.org/wiki/Machine_learning



https://www.gartner.com/it-glossary/machine-learning/

Advanced **machine learning algorithms** are composed of many technologies (such as **deep learning, neural networks** … unsupervised and supervised learning … **guided by lessons from existing information [data].**

Similarities…

Similarities in Neural Networks and State-Based Control

State-Based Representation…

The most general state-space representation of a linear system with p inputs, q outputs and n state variables is written in the following form:[6]

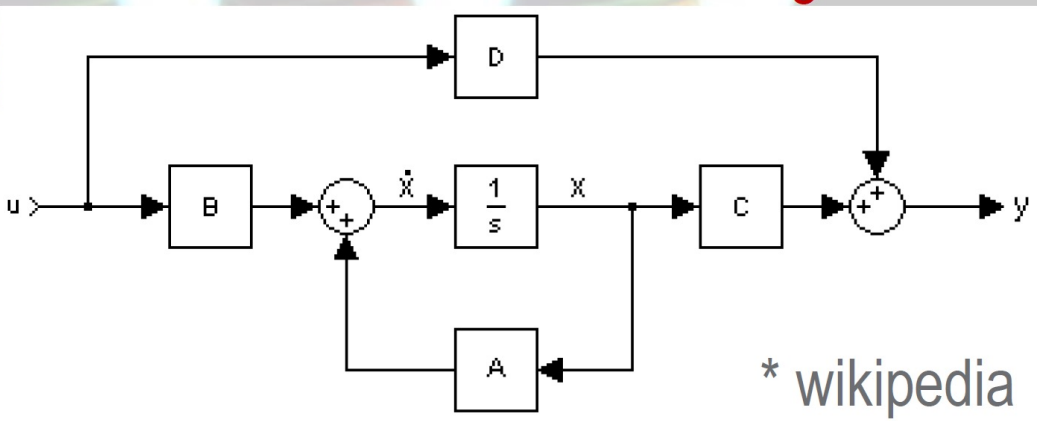
$$\dot{\mathbf{x}}(t) = A(t)\mathbf{x}(t) + B(t)\mathbf{u}(t)$$
$$\mathbf{y}(t) = C(t)\mathbf{x}(t) + D(t)\mathbf{u}(t)$$

where:

$\mathbf{x}(\cdot)$ is called the "state vector", $\mathbf{x}(t) \in \mathbb{R}^n$;
$\mathbf{y}(\cdot)$ is called the "output vector", $\mathbf{y}(t) \in \mathbb{R}^q$;
$\mathbf{u}(\cdot)$ is called the "input (or control) vector", $\mathbf{u}(t) \in \mathbb{R}^p$;
$A(\cdot)$ is the "state (or system) matrix", $\dim[A(\cdot)] = n \times n$,
$B(\cdot)$ is the "input matrix", $\dim[B(\cdot)] = n \times p$,
$C(\cdot)$ is the "output matrix", $\dim[C(\cdot)] = q \times n$,
$D(\cdot)$ is the "feedthrough (or feedforward) matrix" (in cases where the system model does not have a direct feedthrough, $D(\cdot)$ is the zero matrix), $\dim[D(\cdot)] = q \times p$,

$$\dot{\mathbf{x}}(t) := \frac{\mathrm{d}}{\mathrm{d}t}\mathbf{x}(t).$$

Block Diagram…



* wikipedia

Neural Networks

Advanced ML / AI Technique

Neural Network Concept (Similar To) Control Concept

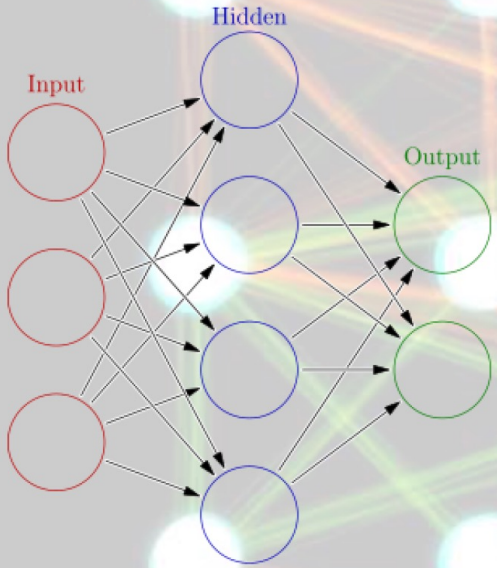
(NN) Back Propagation ➔ Feedback Loop, A(t)X(t)

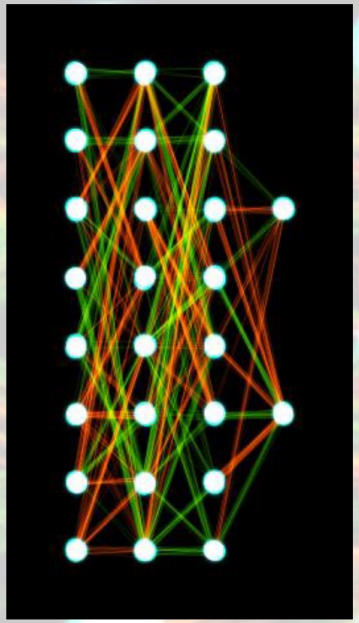
(NN) Gates “Memory”/”State” ➔ Feedforward Loop, D(t)U(t)

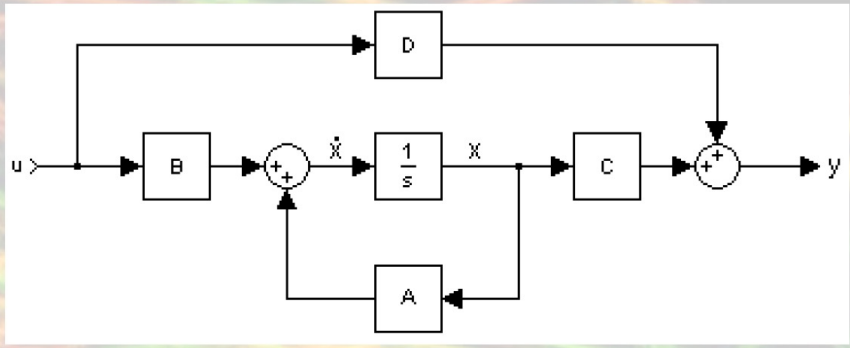
Think… ML / AI is a **Black Box Model**… Leveraging Advanced Statistics and Mathematics

Differences…

Differences in Neural Networks and State-Based Control







1-Layer "Shallow" Neural Network

- 3 Inputs
- 1x4 Hidden Nodes
- 2 Outputs

Multi-Layer (2+) "Deep" Neural Network

- 8 Inputs
- 2x8 Hidden Nodes
- 2 Outputs

Conceptualize "Control Loop" @ Nodes in the Neural Network

Note – "Glossing" over some / a lot of the details for simplicity of concepts

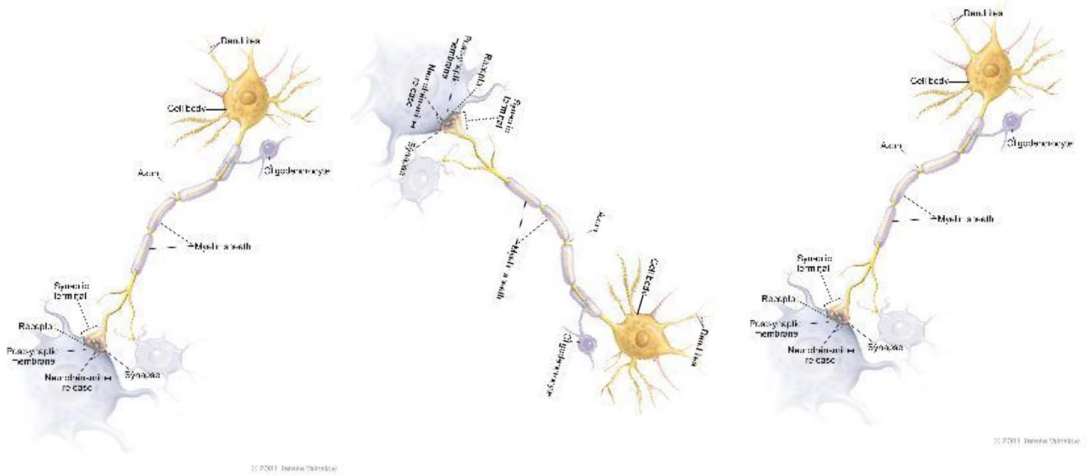
* wikipedia

Think… **Control and ML / AI** Both Leverage Statistics and Mathematics (and Inputs / Outputs)

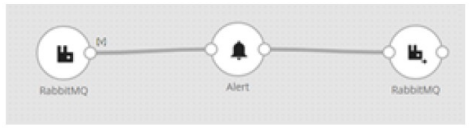
An aside… Related to Neural Networks… HI / AI…

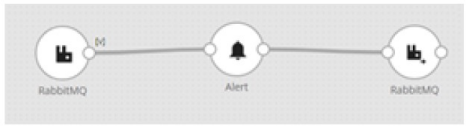
Synapses / Neurons, and Queues / Big Data Pipelines…

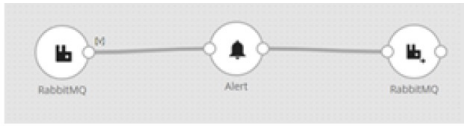
Human Intelligence (HI)



Artificial Intelligence (AI)







Neurons

- Basic Working Unit of the Nervous System
- 100B Neurons in the Brain

Synapses

- “Connectors” between Neurons
- Nerve Impulses (Data) transfer between Neurons…

Nervous System / Brain (Similar To) Big Data Pipelines

Synapses ➔ Queues

Neurons ➔ Individual Big Data Pipeline

Brain ➔ Massive Set of Big Data Pipelines

Note – “Glossing” over some / a lot of the details for simplicity of concepts

* wikipedia

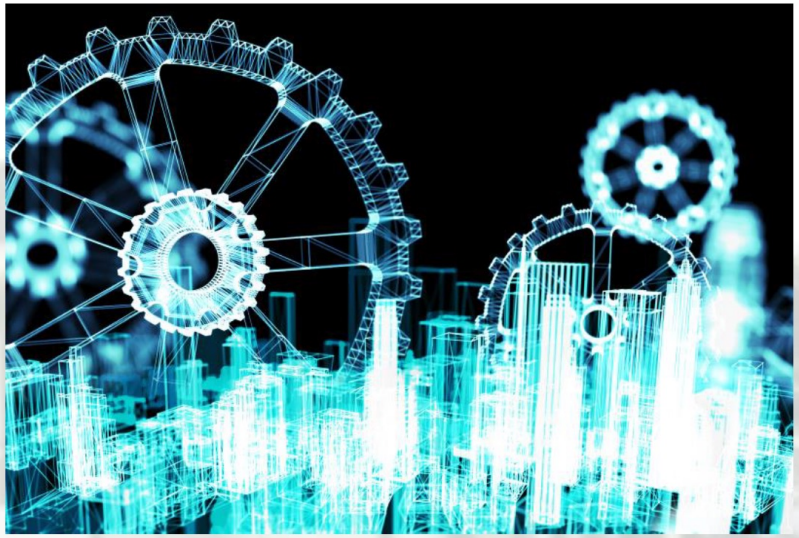
Think… **HI / AI** – Human Intelligence / Artificial Intelligence

Another aside… Related to Learning… HL / AL…

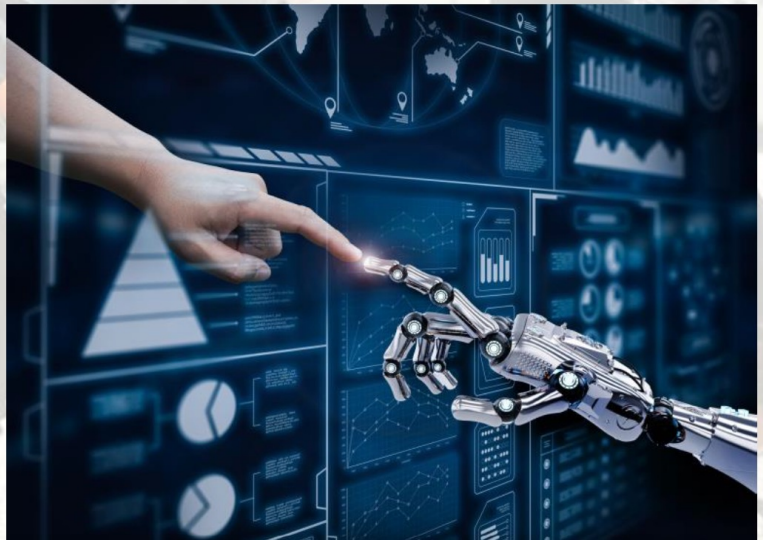
Learning…

Human Learning (HL)

Artificial Learning (AL)



Think… **HL / AL** –
Human Learning / Artificial Learning (aka Machine Learning, ML)



"ET Moment"…
Augmented Learning and Augmented Intelligence…

Analytics Spectrum

BASIC ANALYTICS

ADVANCED ANALYTICS

AUTONOMOUS FACTORIES

ACTION

WHAT HAPPENED?	**WHY DID** IT HAPPEN?	**WHAT IS ABOUT** TO HAPPEN?	**WHAT CAN I DO** TO AVOID IT?	**WRITEBACK** TO CONTROLLER
Motor fault	Motor fault – high current	Motor will fault	Motor will fault, decrease load	Load decreased

Basic Machine Learning

Supervised Learning

Model Training

TensorFlow

Predictive Analytics Process

- Clearly defined business problem
- Set success criteria
- Define clear data science objectives

- Understand data points and constraints
- Formulate data analytics strategy
- Perform required transformation

- Experiment with multiple models
- Choose the most optimal model
- Create a feedback loop

- Put your models to work for you in production
- Data transforms need to be applied
- **Maximum value realized**

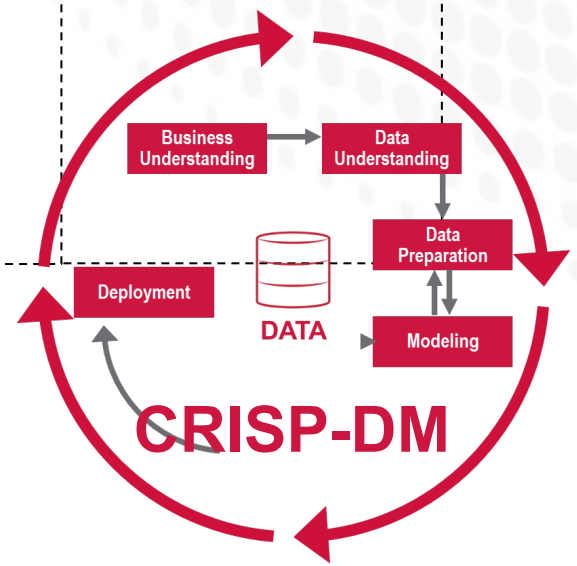
Model Training

Model Scoring

Define Business Problem → Map to Machine Learning Problem → Data Preparation → Exploratory Data Analysis → Modeling → Evaluation → Operationalize

- Break business problems to data science problems
- Identify Machine Learning Problem categories

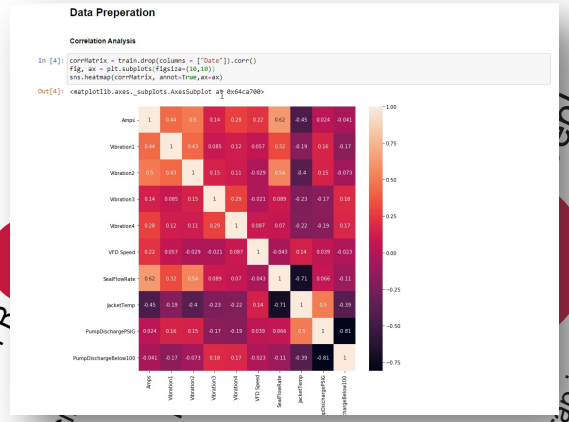
- Perform statistical and visual analysis
- Discover and handle outliers/errors
- Shortlist predictive modeling techniques



Rockwell Automation

Traditional approach to creating Predictions

How are Data Scientists achieving this today…

Interviews with SMEs
Understand Problem
Insights
Identify Data Sources
Feature Engineering
Gather Data
Time Alignment
Wrangle into Shape
Develop Model
Python or R
Sc


ploy
•Expose Inputs
•Return Output
Wrap in Web Service
Connect to Live Data
Call REST service
Actionable Prediction

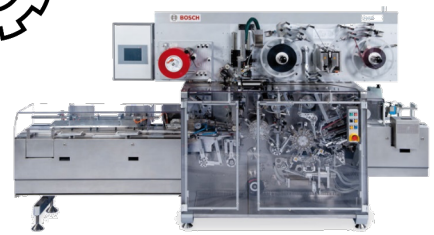
Data Analysis

Data Wrangling Tools

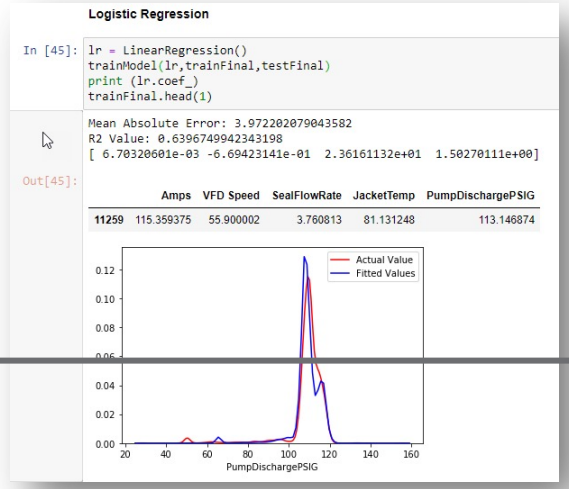
CSV File

Development Environment

SME Community



Various Data Sources



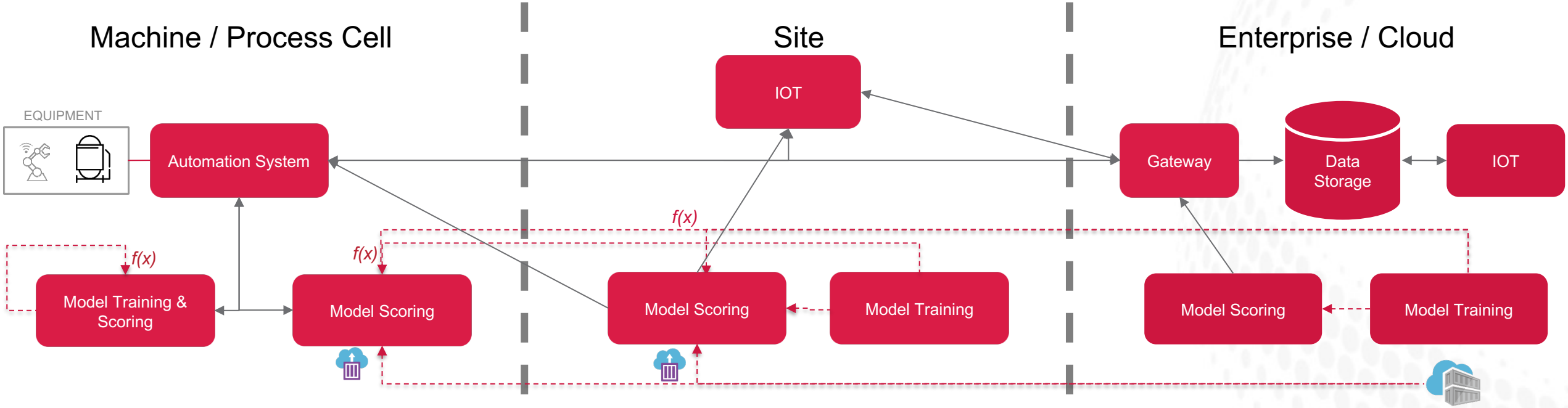
OT Skills

IT Skills

Rockwell Automation

Analytics & Machine Learning Deployment Strategies

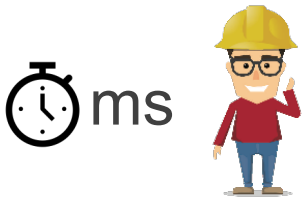
Reference Architecture



Time Horizon	Data Available	Compute	People
msec to sec	Machine-wide	Appliance	Auto / Maint Eng

Time Horizon	Data Available	Compute	People
sec to min	Site-wide	Server	Citizen Data Scientist, Process Eng

Time Horizon	Data Available	Compute	People
hours to days	Enterprise-wide	Scalable	Data Scientist



Consumers of Analytics & ML Results

User and Systems benefit from consuming the prediction

The value is derived from closing the loop

Remote Monitoring Engineer

Support Organization

Your Company

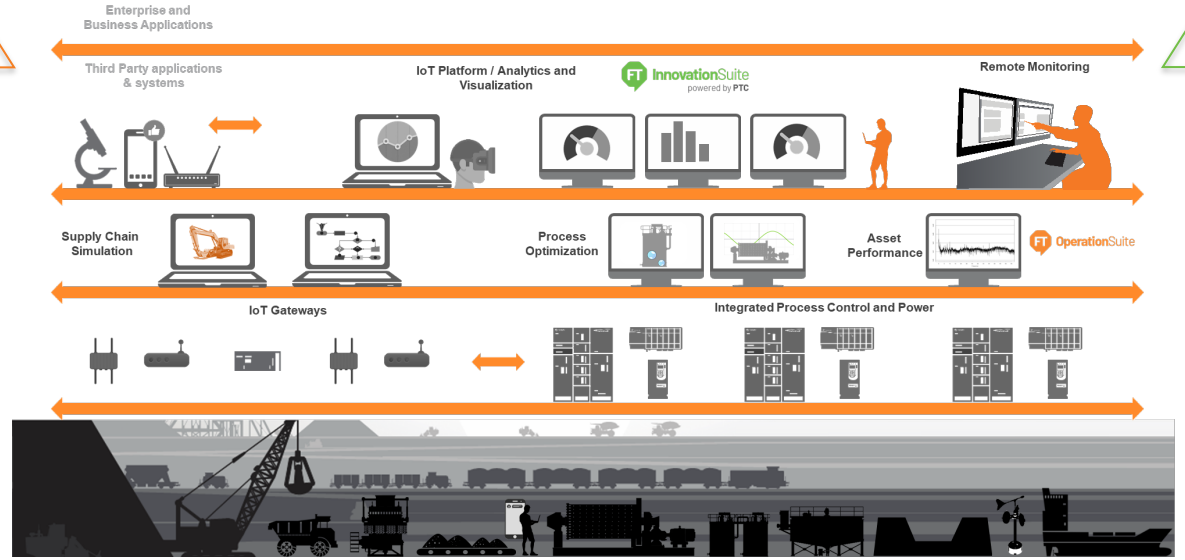
Remote Support Text / Email

Control Room HMI

Maintenance AR

Equipment HMI

PEOPLE



The closer to the Asset, the greater the opportunity

Prediction

Cloud Enterprise Analytics

Cloud

On Premise

IIOT Platform

Convert to Prescriptive Analytic

Application, MQ or Storage

Control Program or Another Analytic

SYSTEMS

Rockwell Automation

Types of Machine Learning

Use Cases vs Techniques

Use Cases

PREDICTIVE
MAINTENANCE

Reduced maintenance costs
Less unplanned downtime
Less production failures
Less process downtime
Reduced maintenance costs

PREDICTIVE
KPIs

Safety / Quality
Less off-spec
Less give-away
Reduced incidents

OPERATIONS
IMPROVEMENTS

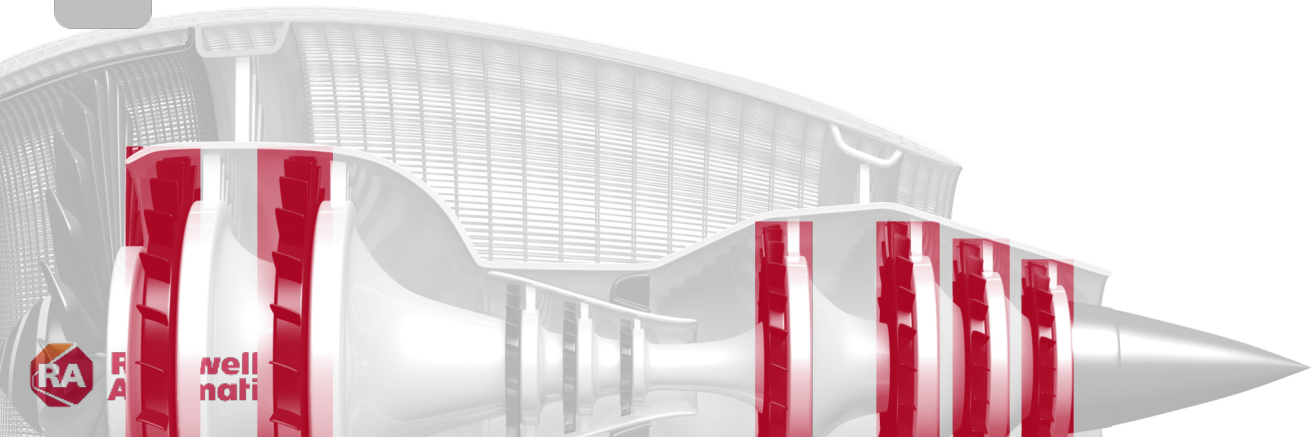
More throughput
Less energy/product
Reduced energy spend
Reduced under-delivered utilities

Techniques

BASIC ML
SUPERVISED LEARNING

MODEL
PREDICTIVE CONTROL

ANOMALY
DETECTION



Anomaly Detection

- System unusual behavior alert
  - Incorrect set-up
  - Wrong/bad feedstock
  - Equipment failure
- Know as soon as something is wrong!
- Provide causal indicators (why).

Predictive Maintenance

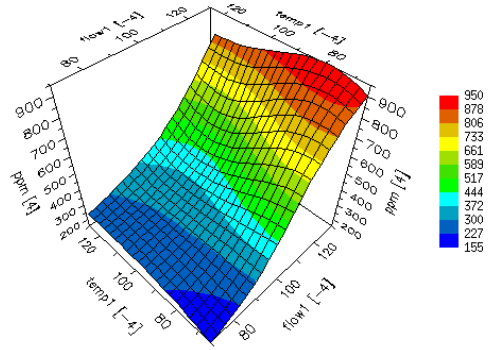
- Avoid unplanned downtime.
- Reduce maintenance to requirements.
- Detect failure early (reduce damage and costs)
- Prioritize maintenance actions
  - Run detection algorithms in parallel to equipment and read/write to MMS/EAM system

Predictive KPI

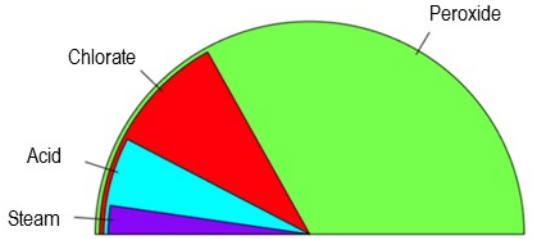
SOFT SENSOR® VIRTUAL ONLINE ANALYZERS

- Lab results in real-time.
- What will production be today?
- What causes poor performance?
- Know now. Reduce knowledge delays.
- Reduce expensive sampling.

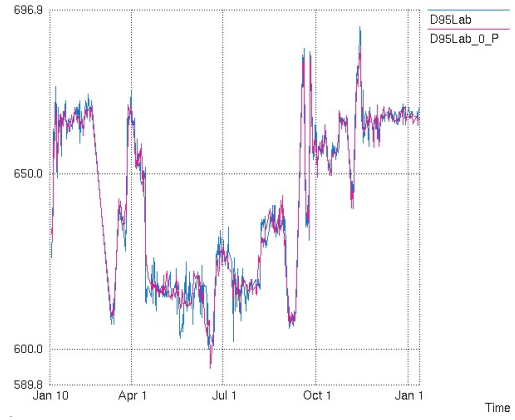
RELATIONSHIPS



CONTRIBUTORS



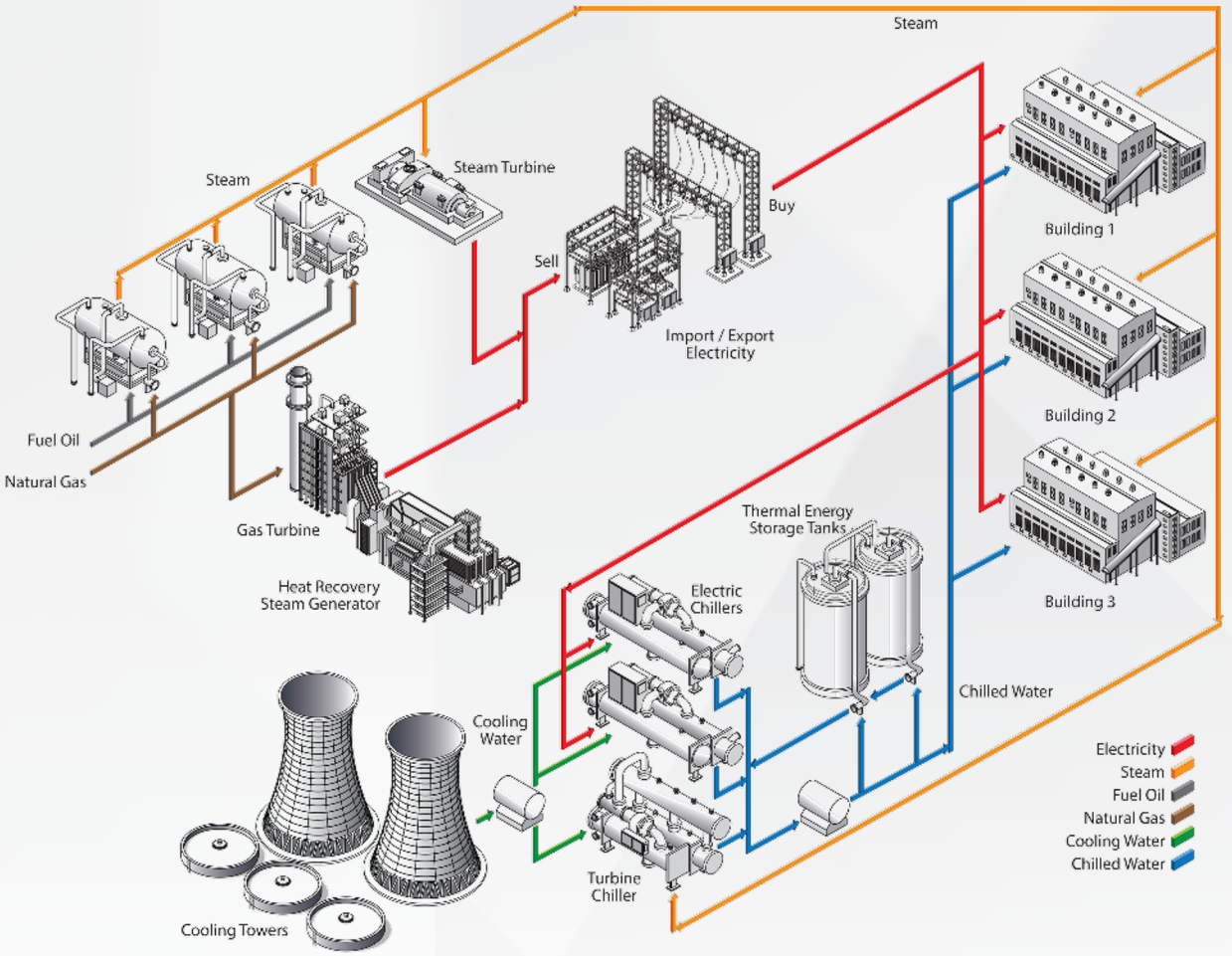
ACCURACY



Energy Optimization

DISPATCH CHILLERS, PUMPS, BOILERS, TURBINES AND COMPRESSORS INTELLIGENTLY AND ECONOMICALLY

- Reduce utility center energy costs
- Maximally use free/low-cost energy
- Operate equipment within limits
- Forecast future demand
  - Graphically layout equipment
  - Automatic model updates
  - Reconcile data for accurate results



Predictive Maintenance Solutions

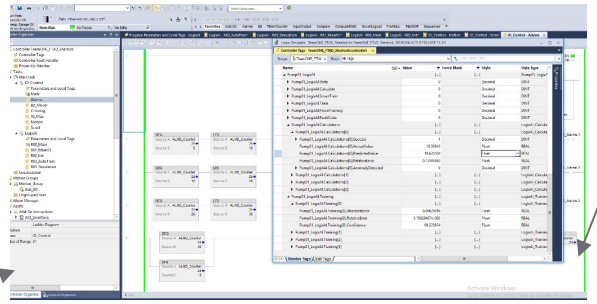
Machine/Process Cell Predictive Analytics

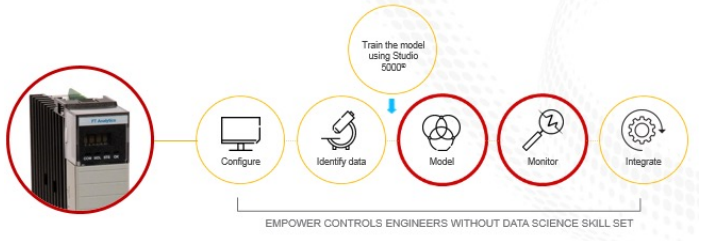
I want automatic ML, as easy as possible.

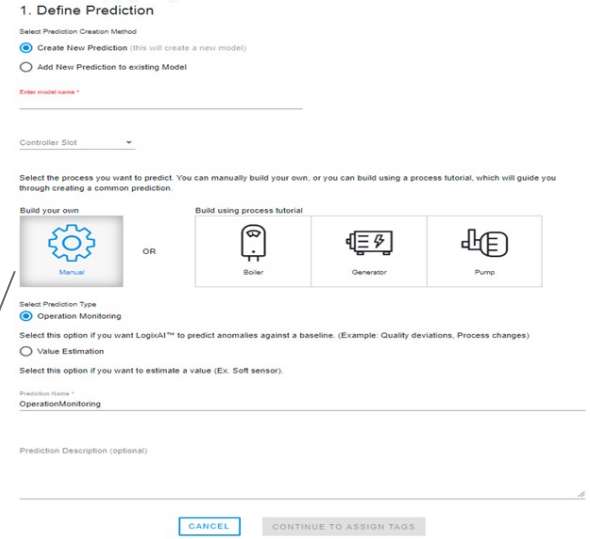
I need something connected to my controller.

Automated Machine Learning Modeling for ControlLogix® Tags. Learn what's normal, find deviations from normal. Estimate values from incomplete data.

FT Analytics™ LogixAI®







Rockwell Automation

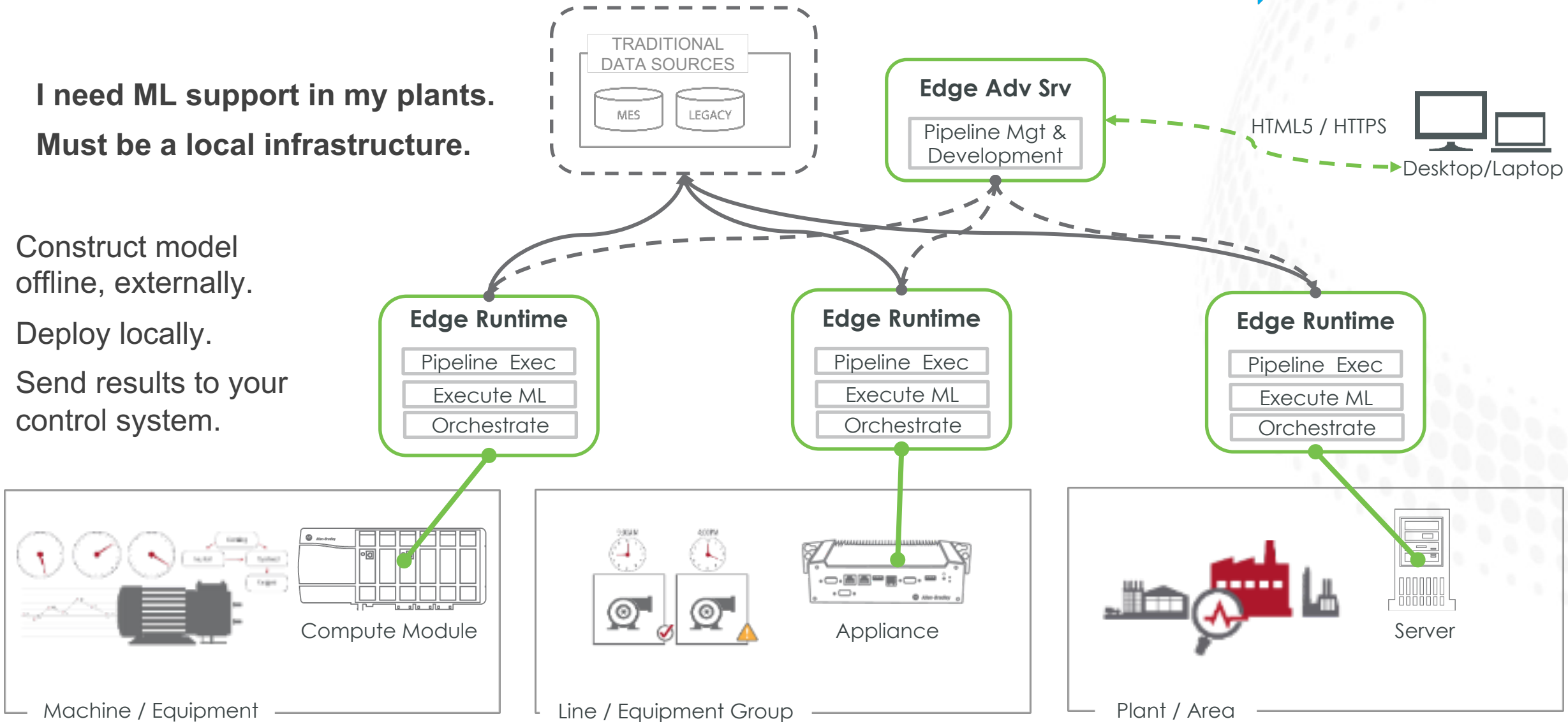
Edge Support High level data flow

FT Analytics™ Edge

I need ML support in my plants.

Must be a local infrastructure.

- Construct model offline, externally.
- Deploy locally.
- Send results to your control system.



Rockwell Automation

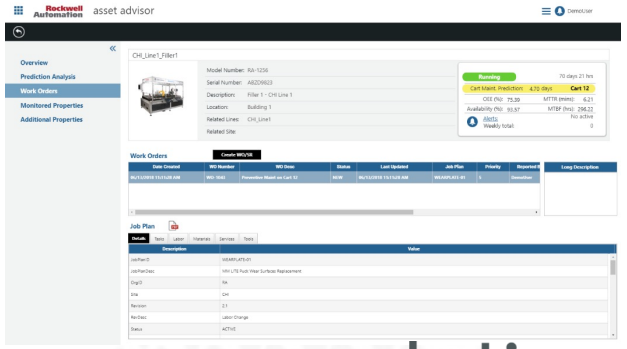
System/Site

I need a simpler way to construct a broad variety of applications.

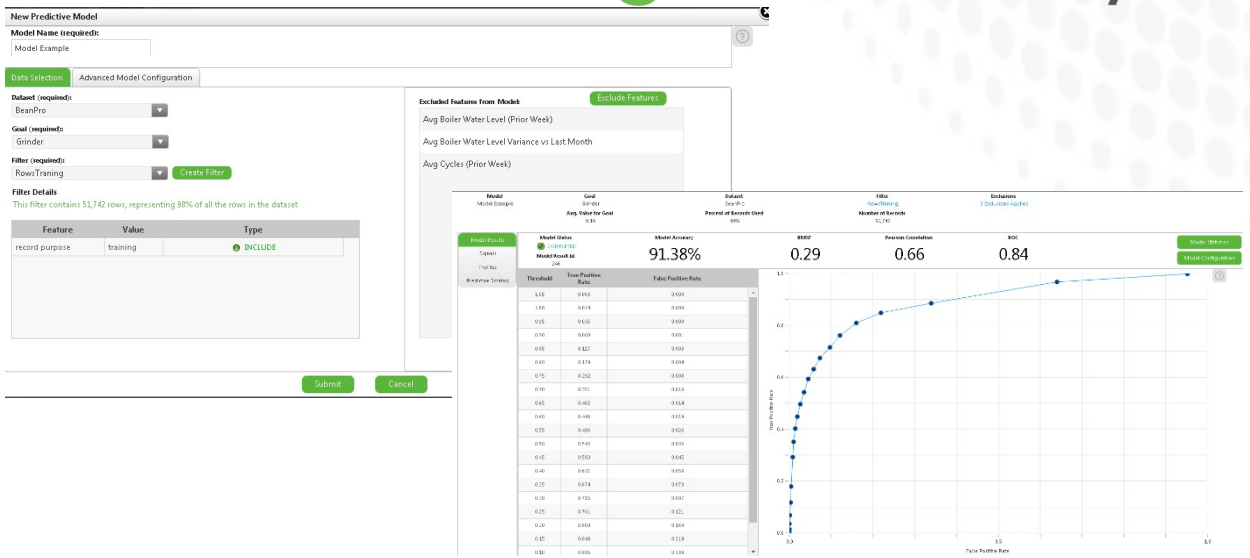
I want to easily deploy & run on an Analytic platform.

- Data Science Citizen supported, open machine learning toolset.
- Supported model deployment in Edge, On-Prem or Cloud with ***FactoryTalk® Analytics™***.
- AutoML toolset for machine learning.

thingworx®



thingworx® analytics™

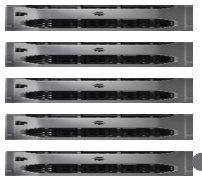


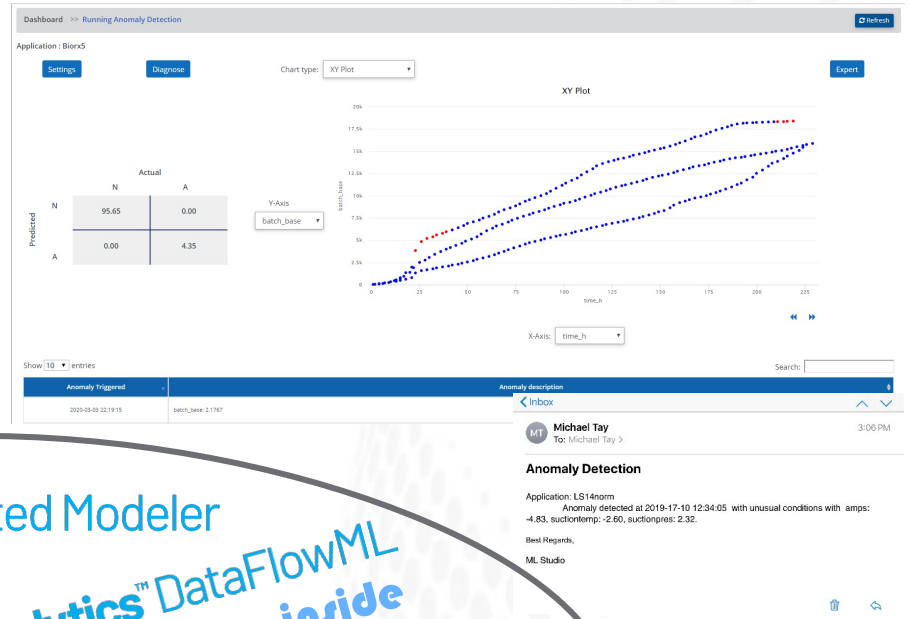
On Prem and Cloud

I want my engineers to leverage what we know about our equipment and data.

I have concerns that ML will be difficult here.

- Visual interactive support.
- Prepare data; data wrangling (explore, clean, enrich, filter).
- Visualize and evaluate model representation.
- Visualize and interact with your online model.
- ML Solution augmentation for ease-of-use.
- Send email alerts or use fit-for-purpose dashboards.





FT Analytics™ Augmented Modeler

FT Analytics™ DataFlowML inside

Construct, Evaluate, Deploy and Visualize model

FT Analytics™ Data Explorer

Prepare data

Future deployment target

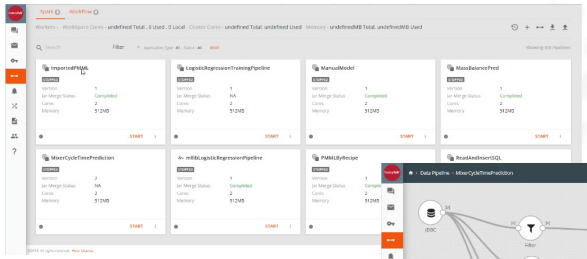
FT Analytics™ Edge

Rockwell Automation

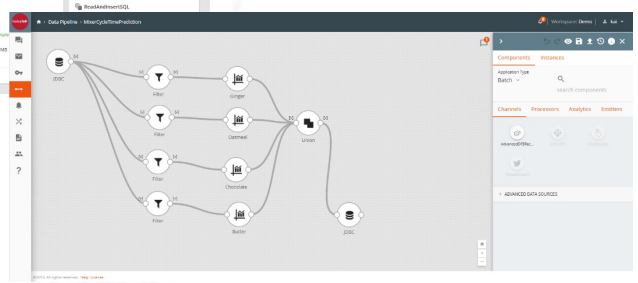
On Prem and Cloud

We need a powerful, enterprise platform for ML.

We want to leverage data science tools we know.



FT Analytics™ DataFlowML



- Open connectivity
- Data preparation, transformation and processing
- Open, extensible platform with machine learning tool integration
- Model building, training and evaluation
- Extremely scalable up to Big Data

jupyter

PMML Predictive Model Markup Language

Spark MLlib The Machine Learning Library

python™

thingworx® analytics™

H2O.ai

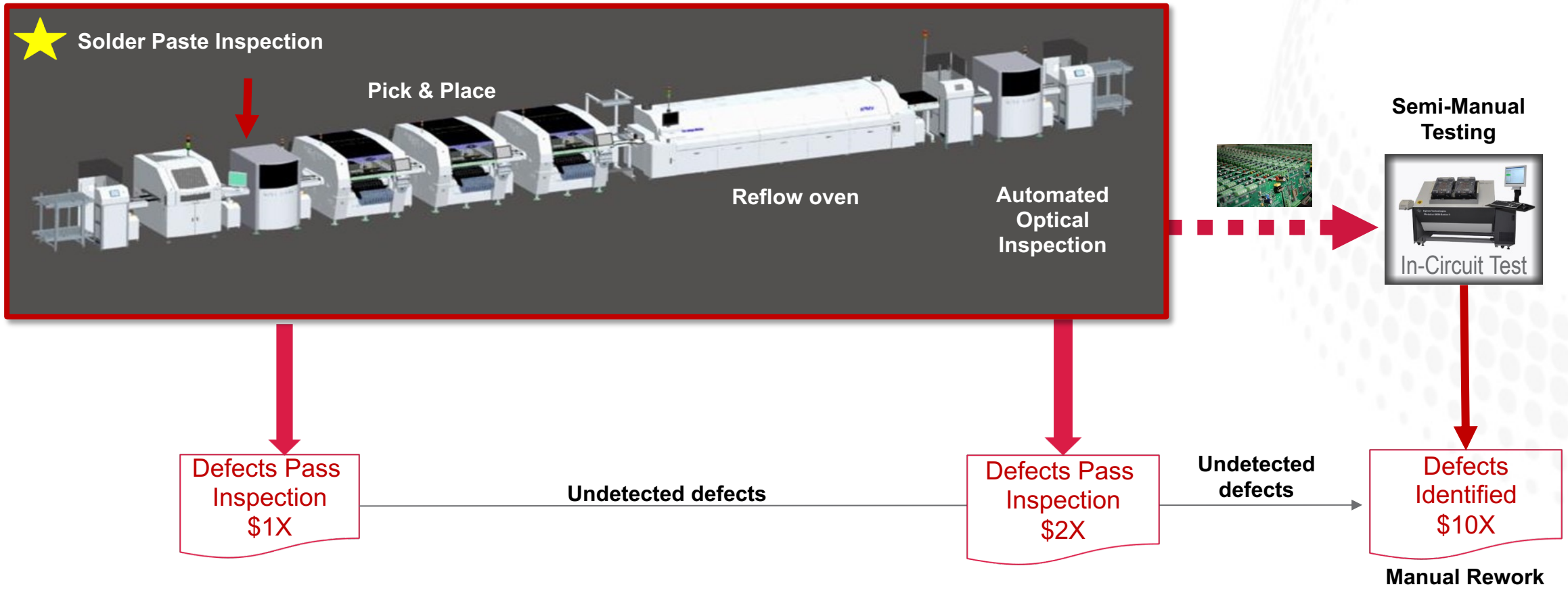
Rockwell Automation

Rockwell Automation

Real-World Predictive Example

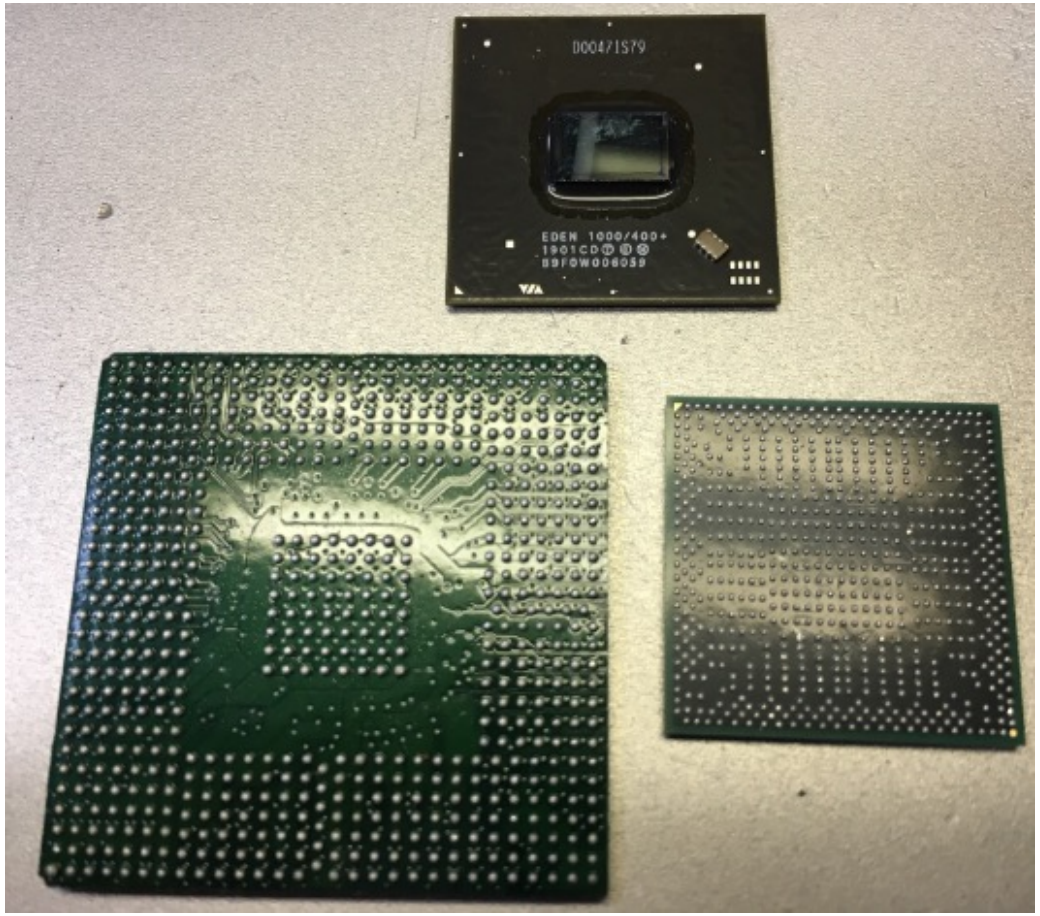
SPI Use Case Baseline State

Reducing Defects in Electronic Assembly Manufacturing of Allen-Bradley® Products

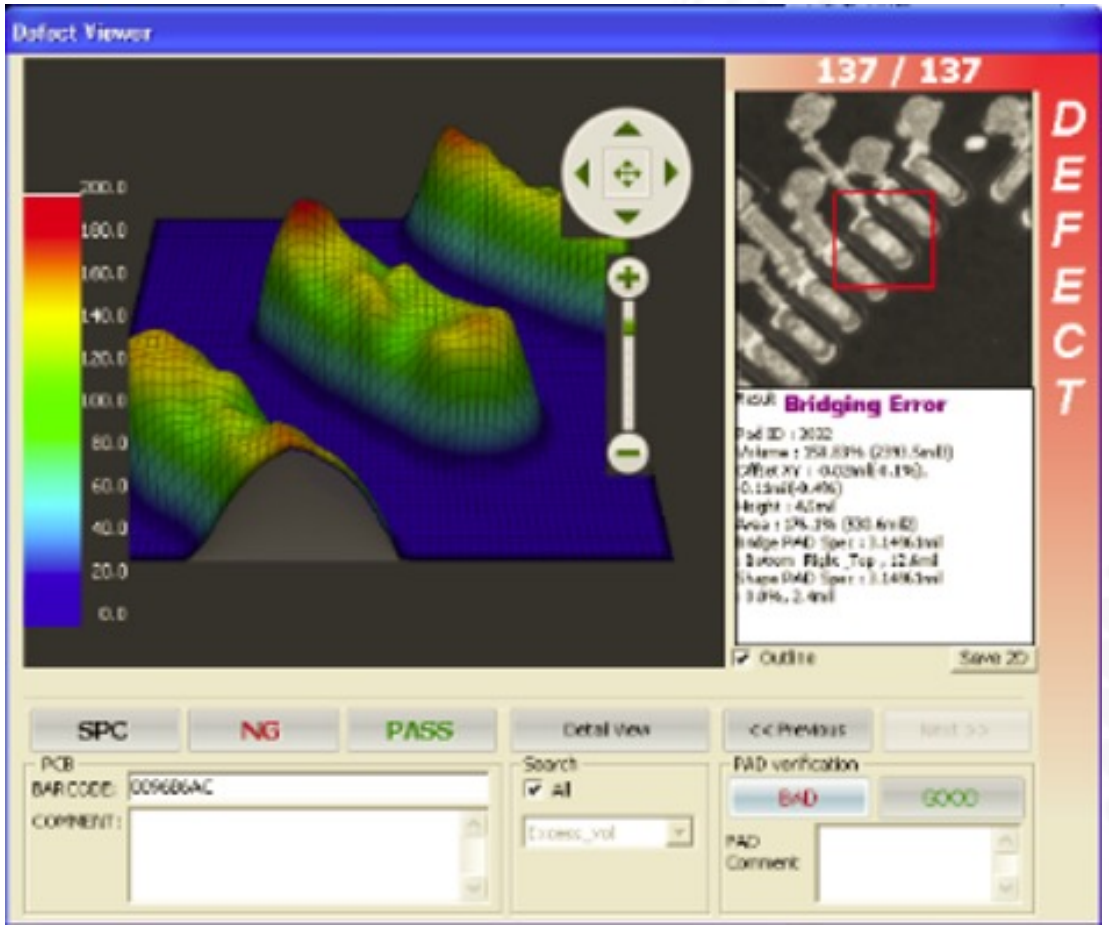


Business Issue: BGA Defects – Costly/Risky/Difficult to Detect

Resolution: Operationalize Closed-Loop Real-Time Defect Prediction System



Typical BGA components
(solder joints are hidden beneath)



Out of the Box SPI inspection only
focuses on individual deposits

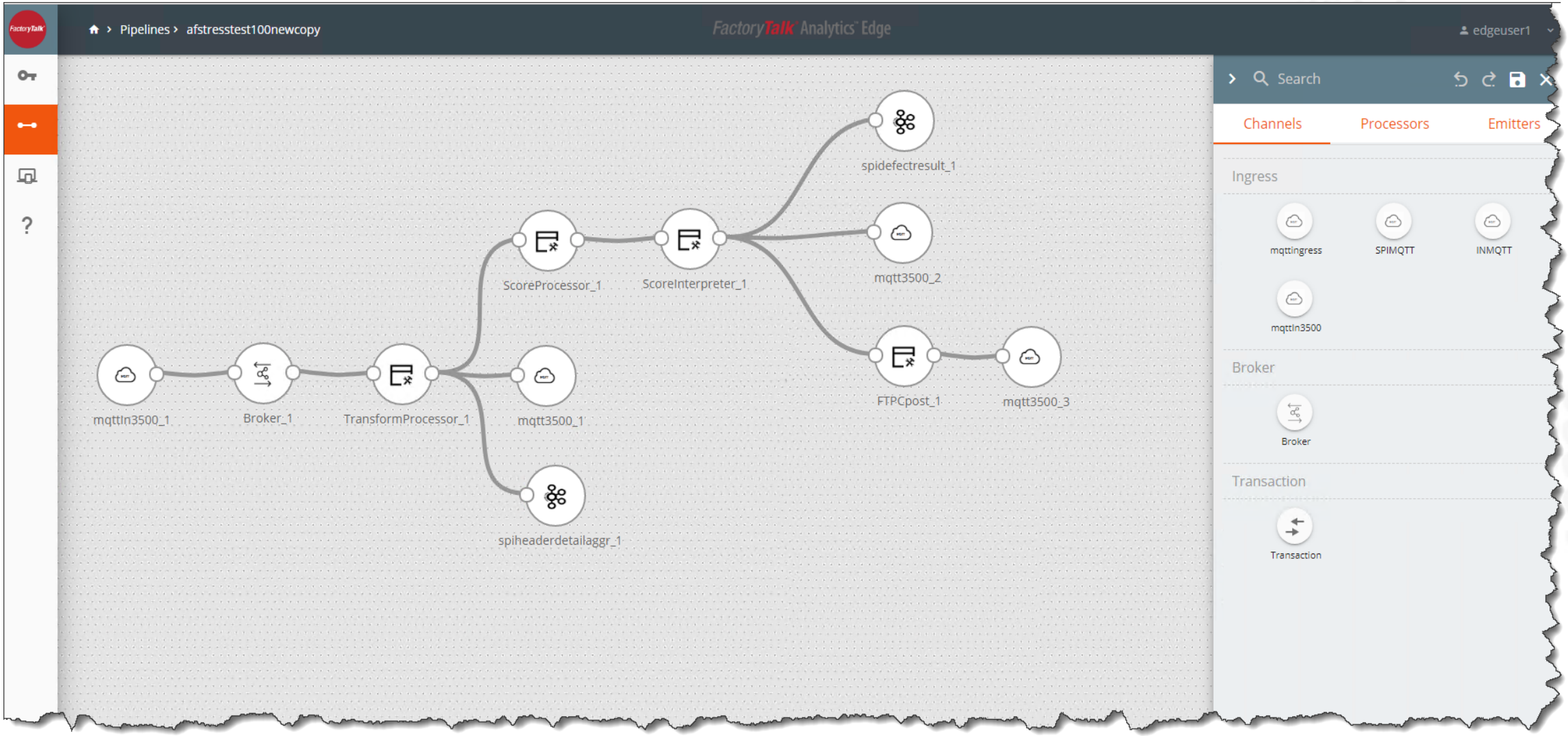
Business Issue: BGA Defects – Costly/Risky/Difficult to Detect cont.

Resolution: Operationalize Closed-Loop Real-Time Defect Prediction System

SPI Output → Edge Prediction (ETL+Scoring) → MES/Line → Enable/Disable Processing to Line

FactoryTalk® Edge Data Pipeline added

Contents of Orange Highlighting from above slide



Rockwell Automation

Wrap Up and Takeaways

Wrap Up and Takeaways

Predictive Maintenance and other advanced analytic solutions deliver performance and intelligent equipment oversight.

- Real world advanced analytics like predictive maintenance are not as easy as frequently wished for or advertised.
- FactoryTalk® InnovationSuite offers a range of the right answers to fit different manufacturing needs.
- You can improve
  - Intelligent Asset Optimization
  - Digital Workforce Productivity
  - Enterprise Operational Intelligence
  - Scalable Production Management
- Today on your Edge, Site or Cloud platforms

Rockwell Automation

expanding **human possibility**™

Thank you

www.rockwellautomation.com