MATLAB EXPO

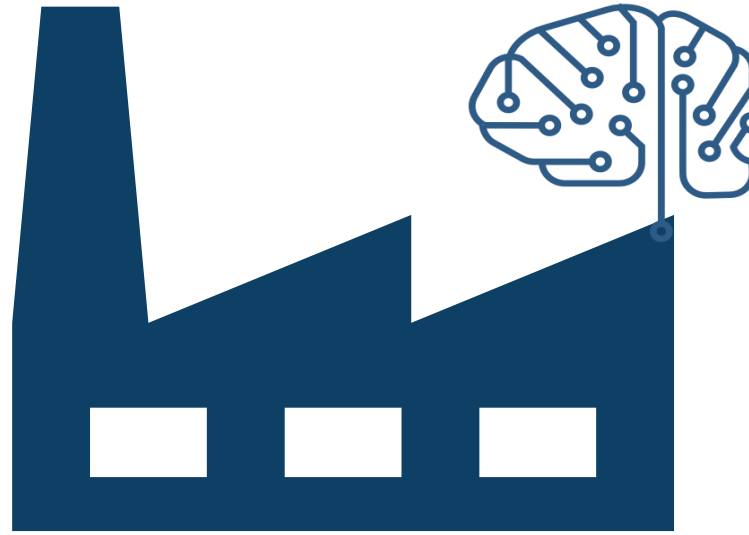
Predictive Maintenance Solution for Smart Manufacturing

Amit Doshi
Principal Application Engineer- Engineering AI

MathWorks®

Smart Factories

Smart factories integrate **autonomy** and **big data** for actionable insights



Connected, optimized, pre-emptive, and agile

- Factories are:
  - Incorporating more advanced **systems**
  - Taking advantage of new **technology**
  - Increasing **connectivity** between components
  - Enhancing **infrastructure** to reach Industrial IoT

Making Factories Smarter: What's the change?

Factories: Traditional Automation

Systems

Fixed-position robots

Technology

Task automation

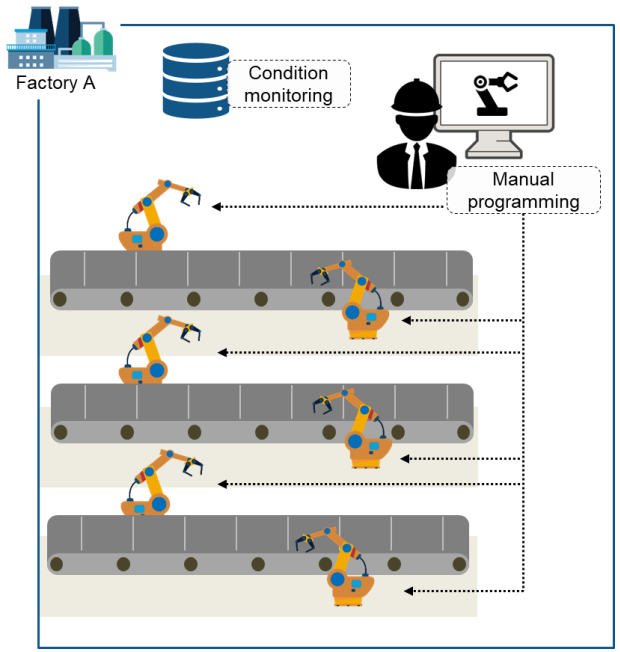
Manual programming

Connectivity

Condition monitoring

Infrastructure

Historians, SCADA



Factories: Leading towards 'Smart'

Systems

Autonomous systems: Collaborative robots, Autonomous Mobile Robots (AMR, AGV)

Technology

AI and Deep Learning (Automated inspections, etc.)

Visualization / AR / VR

Digital twin

Connectivity

Intelligent logistics

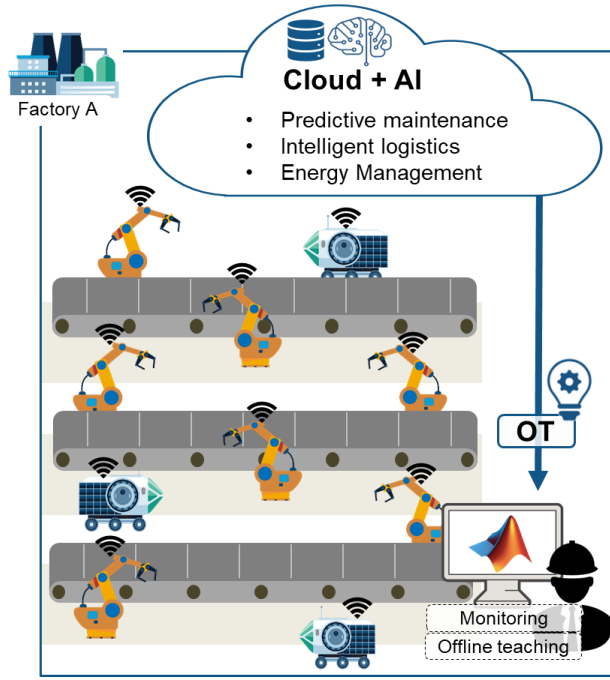
Predictive Maintenance

Infrastructure

Cloud computing

Energy Management

OT (Operational Technology)



Agenda For Today's Talk

1. Predictive Maintenance Algorithm Development
   - Predictive Maintenance Toolbox
2. Algorithm Test & Deployment To Edge Device
   - Simulink Real Time & Simulink Coder
3. Algorithm Deployment to Azure-based IT System
   - MATLAB Compiler & MATLAB Production Server

Predictive Maintenance Promises Improved Operating Efficiency, New Revenue Streams, & A Competitive Differentiator

Siemens
@Siemens
Follow

Thanks to predictive maintenance the #Velaro E trains between Barcelona and Madrid run w/ 99.9% availability #GartnerSYM

ABB Global
@ABBgroupnews
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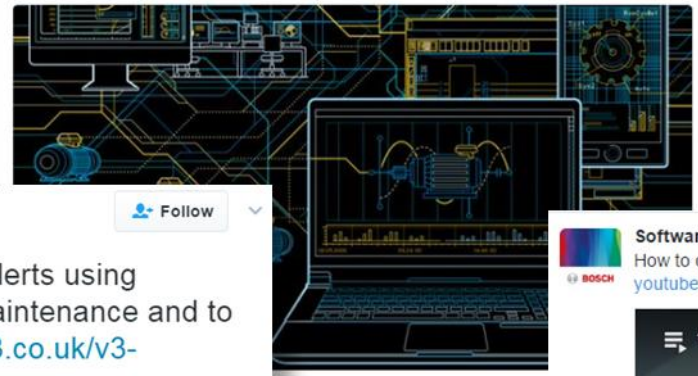
A game changer that opens the door to predictive maintenance ow.ly/4nc2TT #IIot #HM16



Intel IoT
@Inteliot
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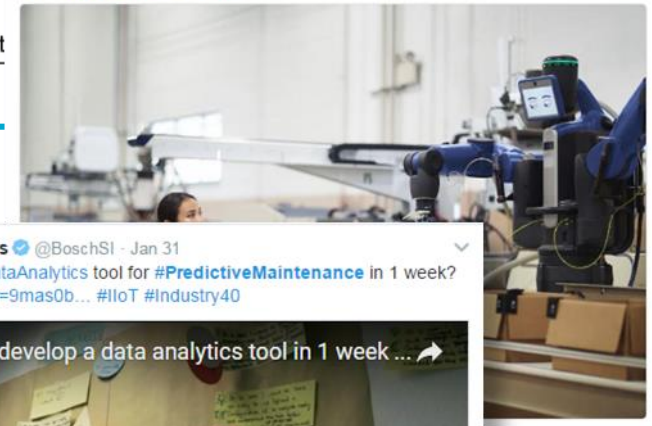
#DYK predictive maintenance can cut yield losses by 25%? Major benefits of #IIoT: intel.ly/2dg7Otm



Impact
ntime Rat

SAP IoT
@SAP_IoT
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John Deere uses machine alerts using #telematics for predictive maintenance and to lower downtime of assets v3.co.uk/v3-uk/news/234 … #IoT

John Deere: Technology vendors need to feed agriculture's big data needs
Farmers are hungry for IT solutions
v3.co.uk

Planned
nance Approach

Software Innovations @BoschSI · Jan 31
How to develop a #DataAnalytics tool for #PredictiveMaintenance in 1 week?
youtube.com/watch?v=9mas0b… #IIoT #Industry40

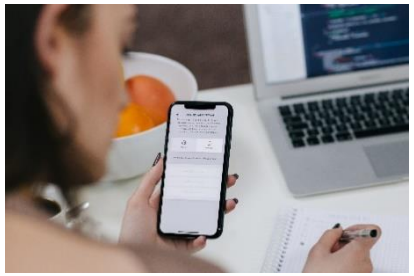
How to develop a data analytics tool in 1 week (Part 1)
A team of data scientists, manufacturing & software experts at Bosch Software Innovations developed a data analytics tool for predictive maint...
youtube.com

Predictive Maintenance Matters To Every Single Industry That Is Manufacturing Or Operating Machinery

Aerospace and Defense

Automotive

Medical Devices



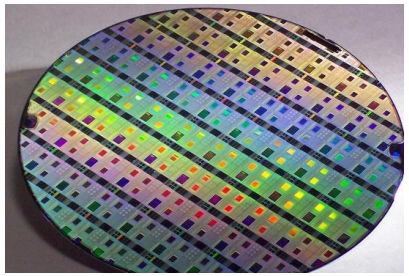
Electronics

Energy Production

Industrial Machinery

Process Manufacturing

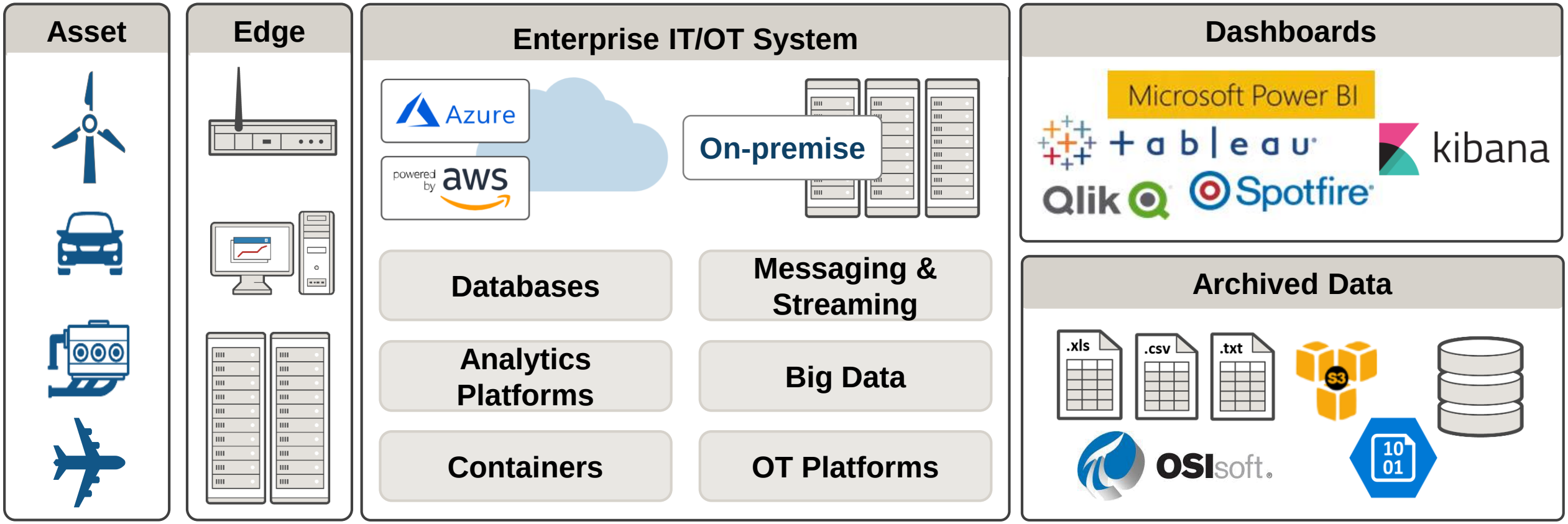
Railway Systems



Semiconductors

MATLAB & Simulink Are Being Used Today For Predictive Maintenance

…But Deploying a Predictive Maintenance Algorithm Successfully Is Much More Complicated



The Challenges Associated With Predictive Maintenance Are Consistent Across Industries, for both Data Scientists & Engineers

Too many options for machine learning, feature extraction, etc.

Integrating algorithms with existing infrastructure

Lack of failure data

Hard to get started

Case Study: Flow Pack Machine

Objective:
Using machine data, determine what needs to be fixed and estimate RUL

Challenge:
Failure sensor data is not available

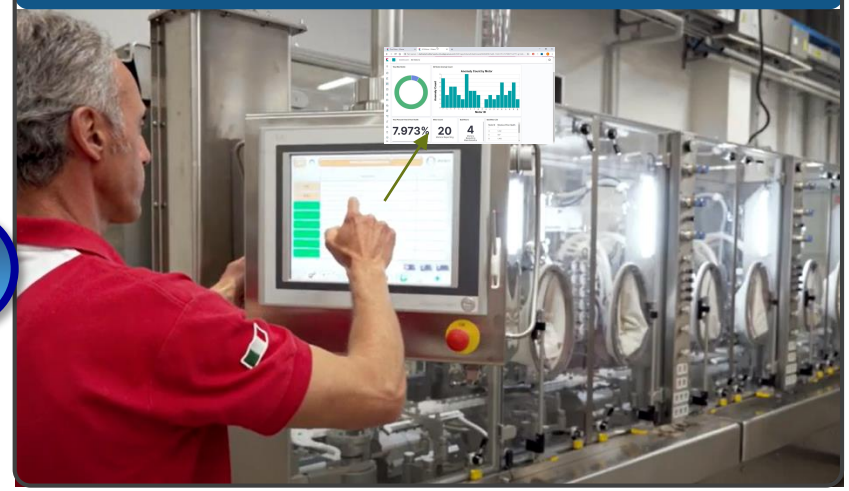
Data

PdM Algorithm Development

1

- Motor Current
- Motor Speed
- Position Error

Dashboard for the end users

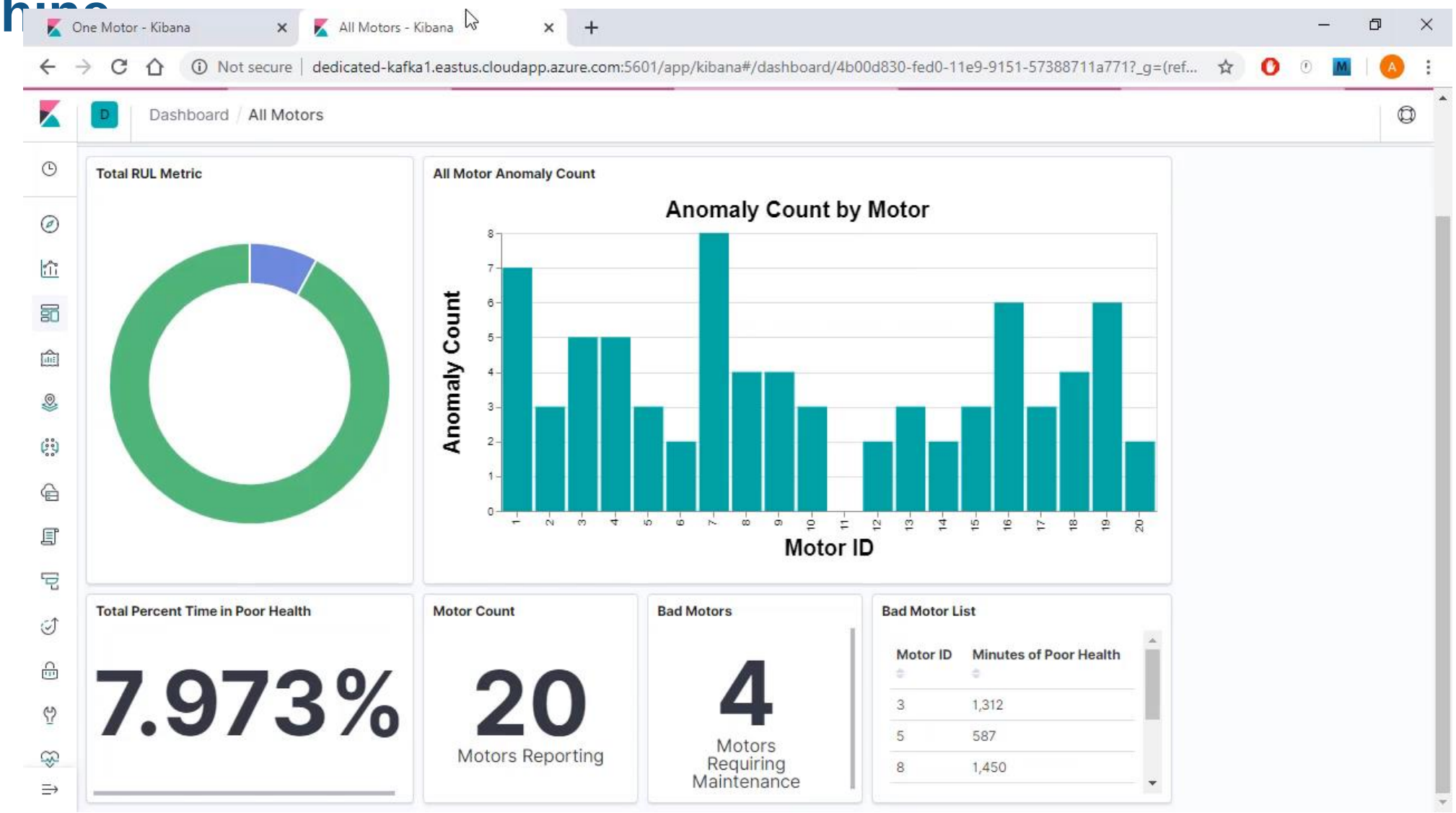


3

Deploy PdM on the edge

2

Case Study: Flow Pack Machine



Algorithm Development Includes Remaining Useful Life Estimation, Anomaly Detection, Fault Classification, & Condition Monitoring

1. Predictive Maintenance Algorithm Development
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2. Algorithm Test & Deployment To Edge Device
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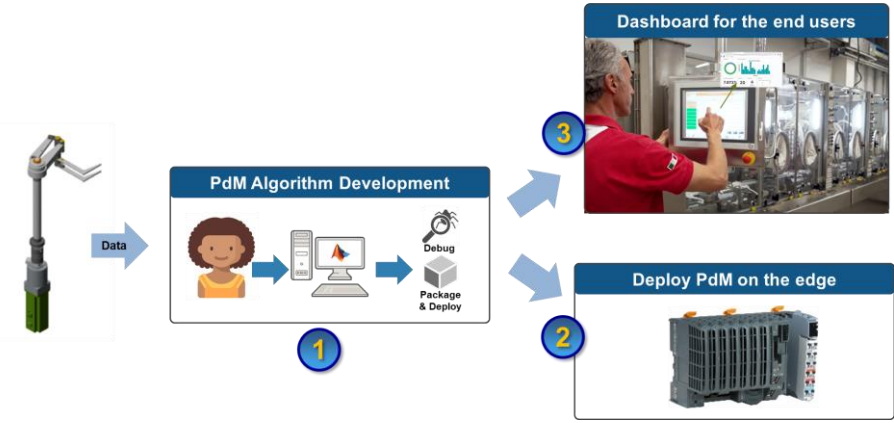
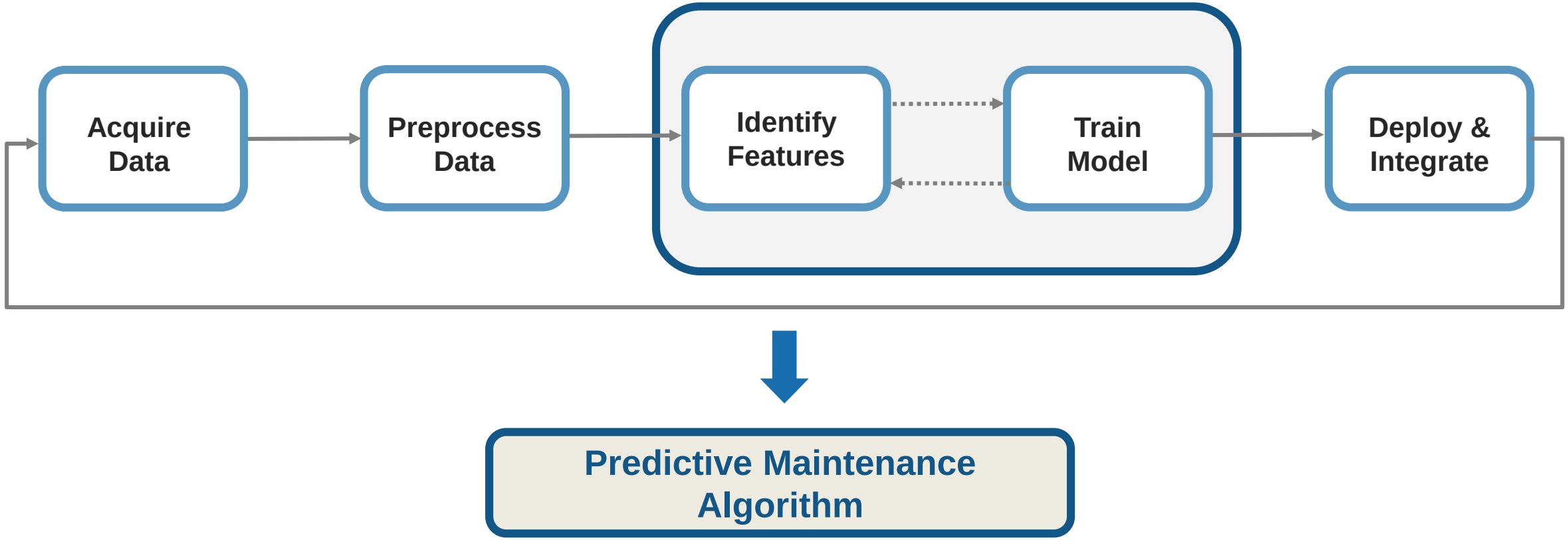
3. Algorithm Deployment to Azure-based IT System
   - MATLAB Compiler & MATLAB Production Server

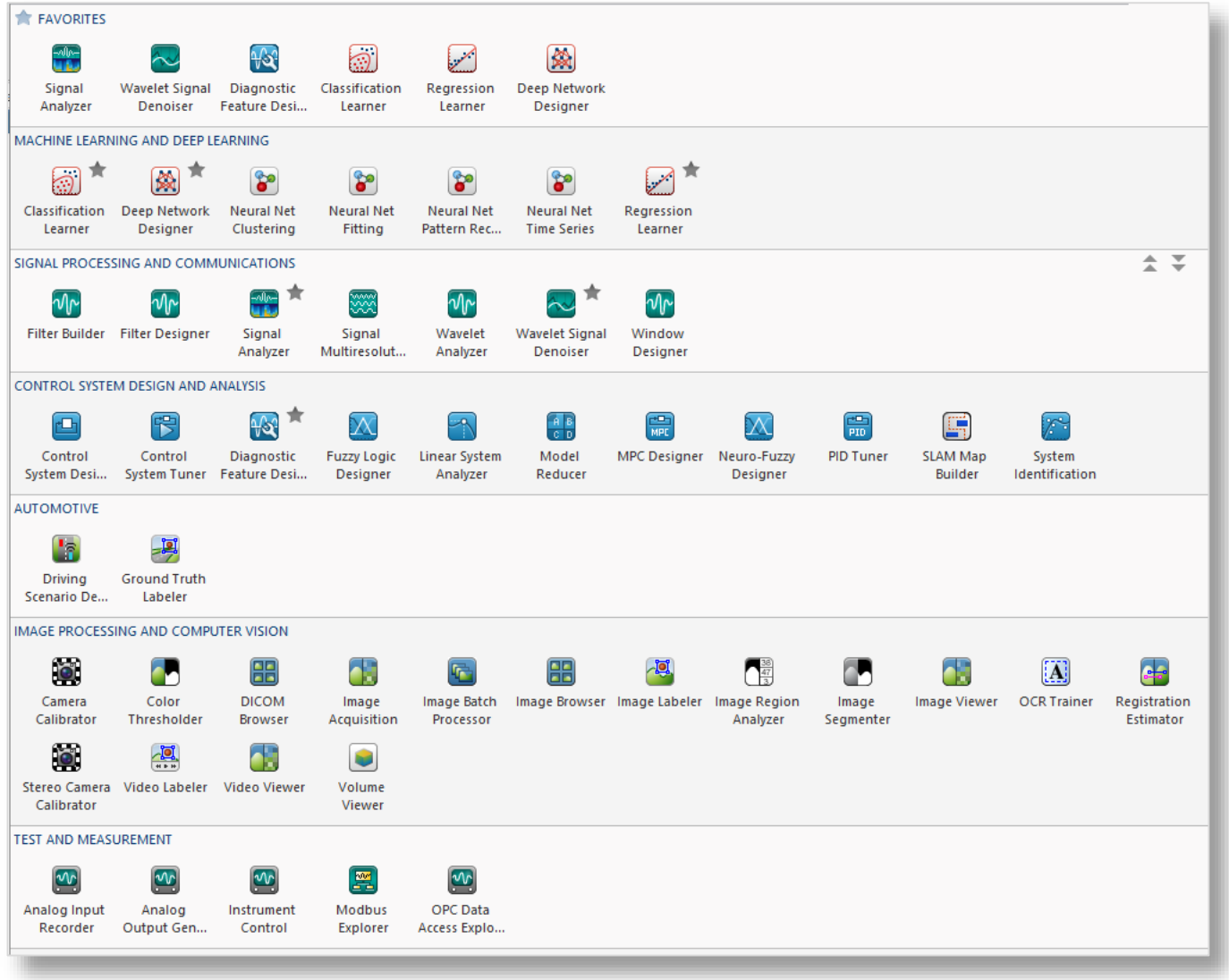


Developing A Predictive Maintenance Algorithm Requires Domain Expertise and Machine Learning Techniques…

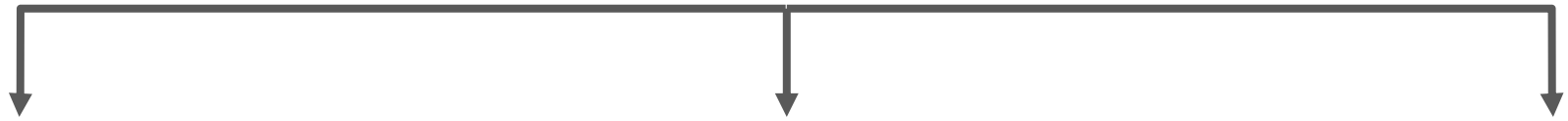


Explore and automate feature extraction & machine learning tasks using MATLAB Apps

- Signal Analyzer
- Wavelet Denoiser
- Diagnostic Feature Designer
- Classification Learner
- Regression Learner
- Deep Network Designer
- …and many more



Signal-Based Condition Indicators



Time-domain features

Mean
Standard deviation
Skewness
Root-mean square
Kurtosis
⋮

Frequency-domain features

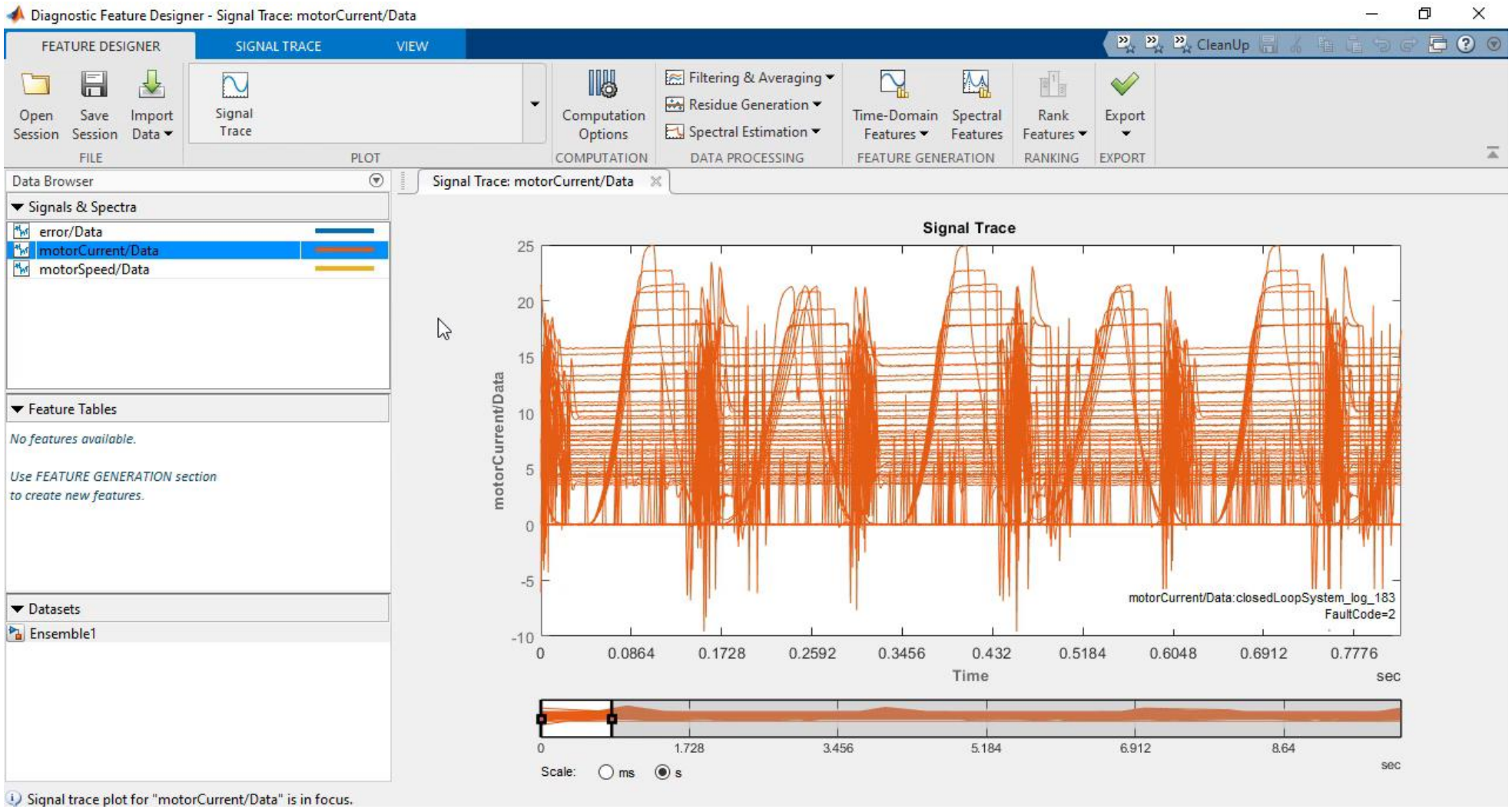
Power bandwidth
Mean frequency
Peak values
Peak frequencies
Harmonics
⋮

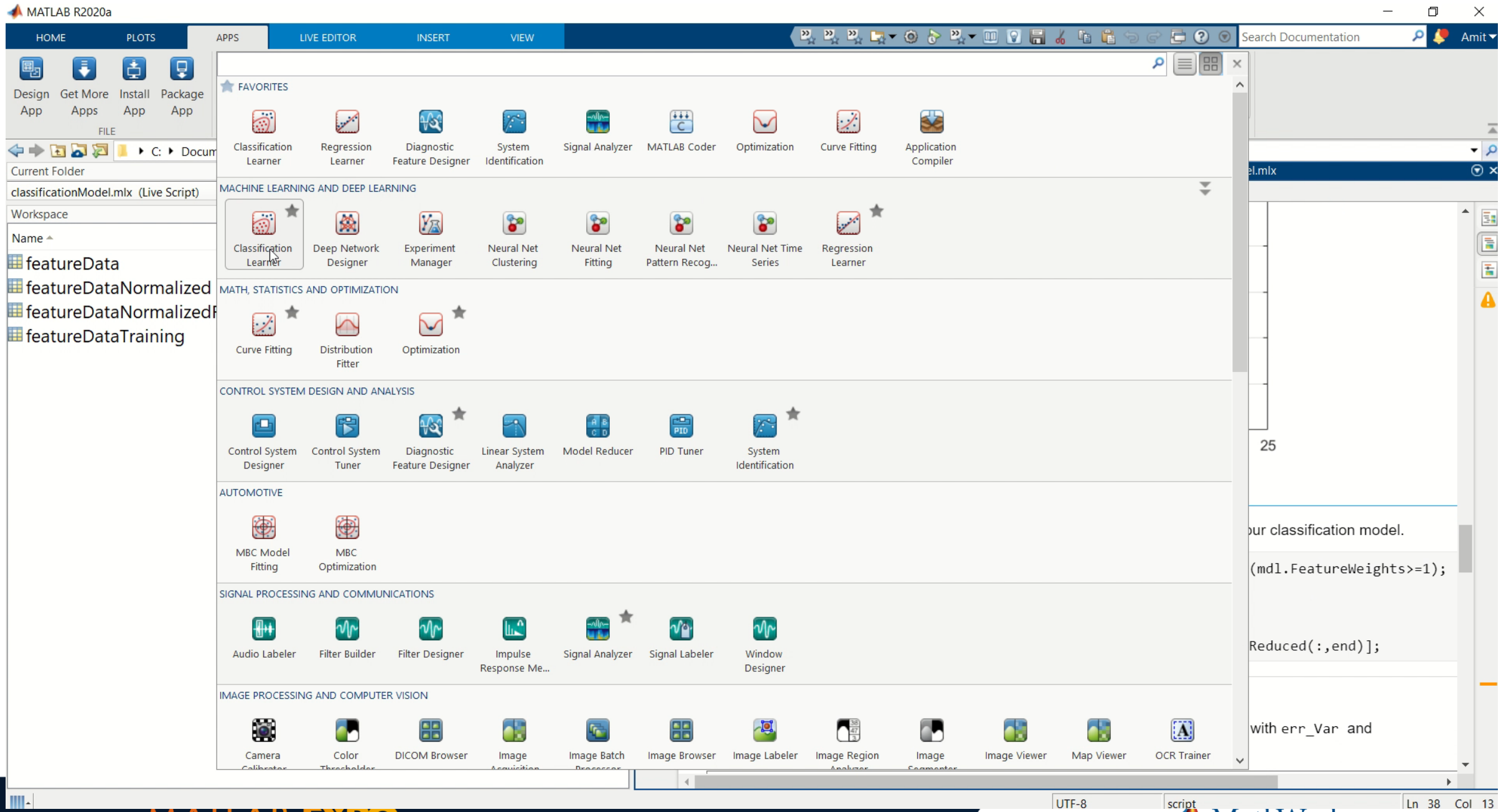
Time-frequency domain features

Spectral entropy
Spectral kurtosis
⋮

Learn more about Condition Indicators

Visualize Data, Try Different Feature Extraction Methods & Compare Results Without Writing Any MATLAB Code




MATLAB R2020a
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Package App
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Classification Learner
Regression Learner
Diagnostic Feature Designer
System Identification
Signal Analyzer
MATLAB Coder
Optimization
Curve Fitting
Application Compiler
MACHINE LEARNING AND DEEP LEARNING
Classification Learner
Deep Network Designer
Experiment Manager
Neural Net Clustering
Neural Net Fitting
Neural Net Pattern Recog...
Neural Net Time Series
Regression Learner
MATH, STATISTICS AND OPTIMIZATION
Curve Fitting
Distribution Fitter
Optimization
CONTROL SYSTEM DESIGN AND ANALYSIS
Control System Designer
Control System Tuner
Diagnostic Feature Designer
Linear System Analyzer
Model Reducer
PID Tuner
System Identification
AUTOMOTIVE
MBC Model Fitting
MBC Optimization
SIGNAL PROCESSING AND COMMUNICATIONS
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Filter Builder
Filter Designer
Impulse Response Me...
Signal Analyzer
Signal Labeler
Window Designer
IMAGE PROCESSING AND COMPUTER VISION
Camera Calibrator
Color Thresholder
DICOM Browser
Image Acquisition
Image Batch Processor
Image Browser
Image Labeler
Image Region Analyzer
Image Segmenter
Image Viewer
Map Viewer
OCR Trainer
Current Folder
classificationModel.mlx (Live Script)
Workspace
Name
featureData
featureDataNormalized
featureDataNormalizedR
featureDataTraining
25
our classification model.
(mdl.FeatureWeights>=1);
Reduced(:,end)];
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UTF-8
script
Ln 38 Col 13

Metro de Madrid and IMA Are Using MATLAB For Developing Predictive Maintenance Algorithms

Metro de Madrid Adopts Machine Learning for Predictive Maintenance in Tunnels

Raúl Rico, Metro de Madrid

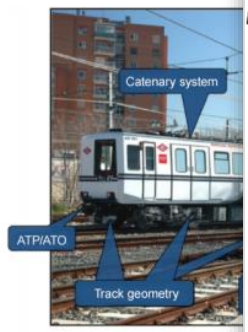
Every day, Metro de Madrid stores more than 10 GB of new data acquired from different sources. Many available tools can only analyze data from a single sensor, and such approaches lack domain expertise. In order to use all the data they acquire for predictive maintenance, Metro de Madrid needed to integrate the data from a wide variety of sensors and customize their signal analysis algorithms.

Metro de Madrid used MATLAB® and Statistics and Machine Learning Toolbox™ to automate the data merging, signal analysis, and algorithm sharing, which enables people without MATLAB experience to perform advanced signal analysis.

Advantages of using MATLAB:

- Save time in the data validation and analysis phase
- Integrate data from different sources
- Share algorithms with non-MATLAB users

> "We have created a **degradation model** of the catenary that allows us to **anticipate and optimize** the **maintenance actions**."



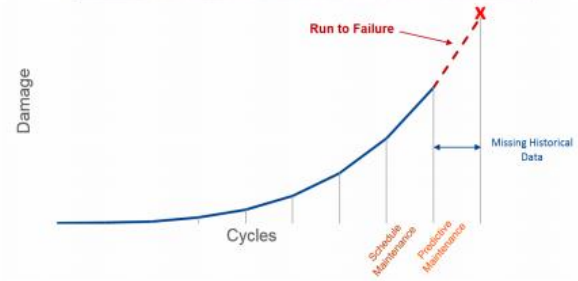
IMA ACTIVE

Conclusions and Future Activities

- Using MATLAB tools we managed to extract and select the best features to build a classification model
- The most promising algorithm uses 5 features and has an accuracy of 89%
- Ongoing: check capability of generalization using data of other parts that did not break
- In the future: acquire new data and test the model on-line

Safran Uses Simulink to Generate Failure Data To Train Neural Networks To Detect Anomalies and Predict Failures in Factories

Engineering Technology – Digital Twin



1. Due to traditional Maintenance Cycles, run-to-failure data are normally missing from collected Data Base.
2. Run-to-failure data are necessary for Smart Prediction.
3. Digital Twins simulate anomalies to generate these data.
4. Digital Twins follow Physical Responses.

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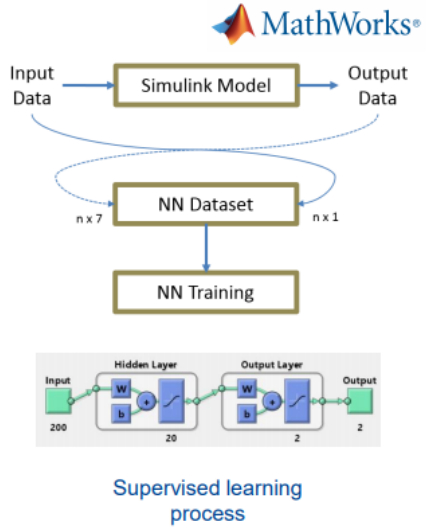
Application – Hydraulic Press

1. **Data base**
   - NN Dataset & Training is developing by switching Input-Output.
2. **ANN Generation**
   - Build the ANN architecture with Deep Learning Toolbox.
3. **Training**
   - Adjust relative neural parameters to reach desired values.
4. **Validation**
   - Iterative process using physical inputs to validate ANN and Virtual Model.



Supervised learning process

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[MATLAB Expo Talk Link]

Edge Device Deployment Enables Data Reduction & Faster Results

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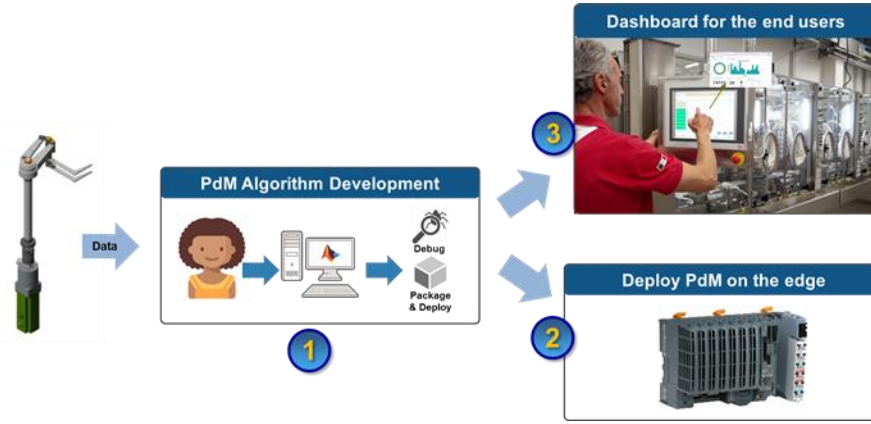
   - Predictive Maintenance Toolbox

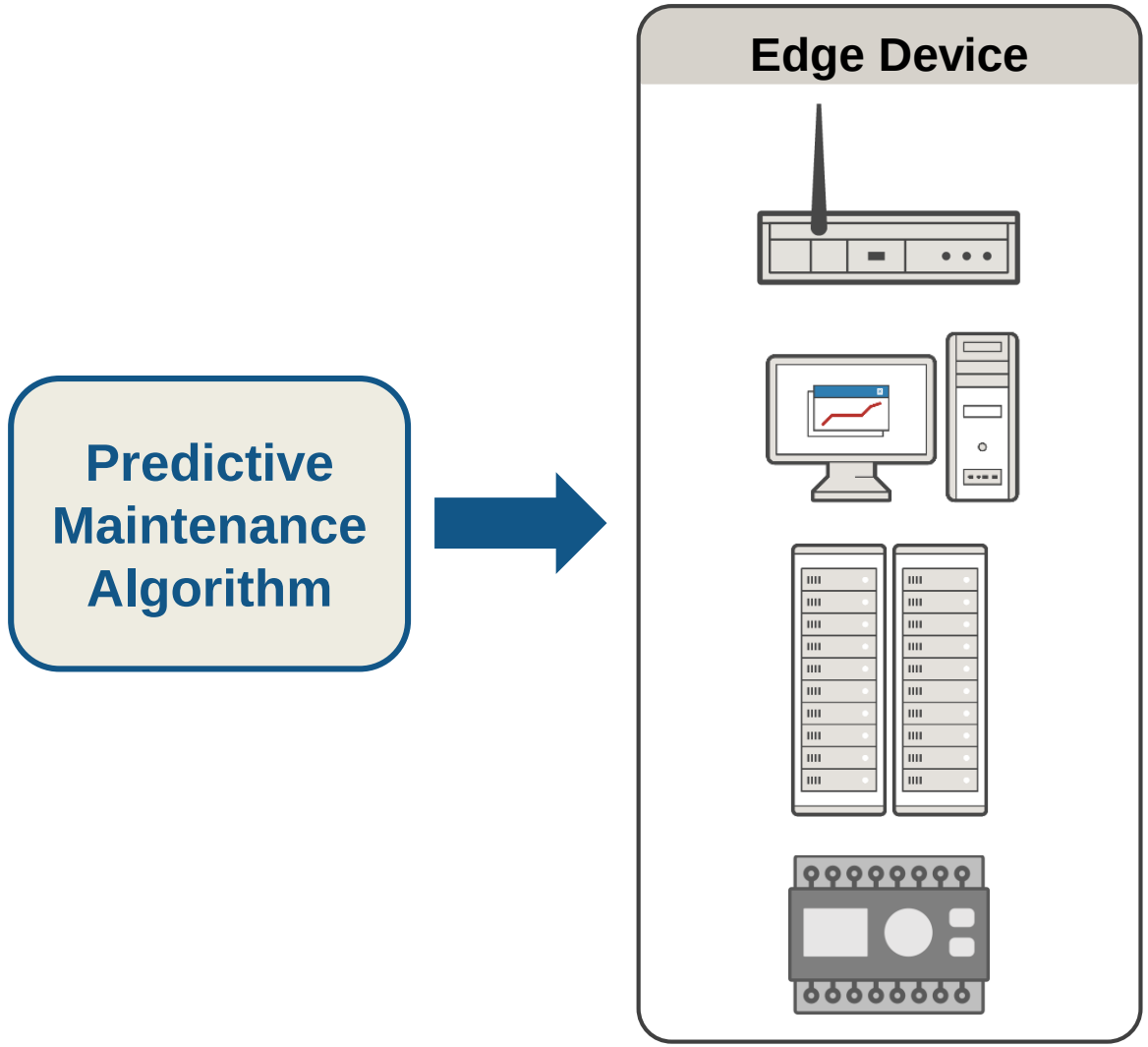
2. **Algorithm Test & Deployment To Edge Device**
   - Simulink Real Time & Simulink Coder

3. Algorithm Deployment to Azure-based IT System
   - MATLAB Compiler & MATLAB Production Server

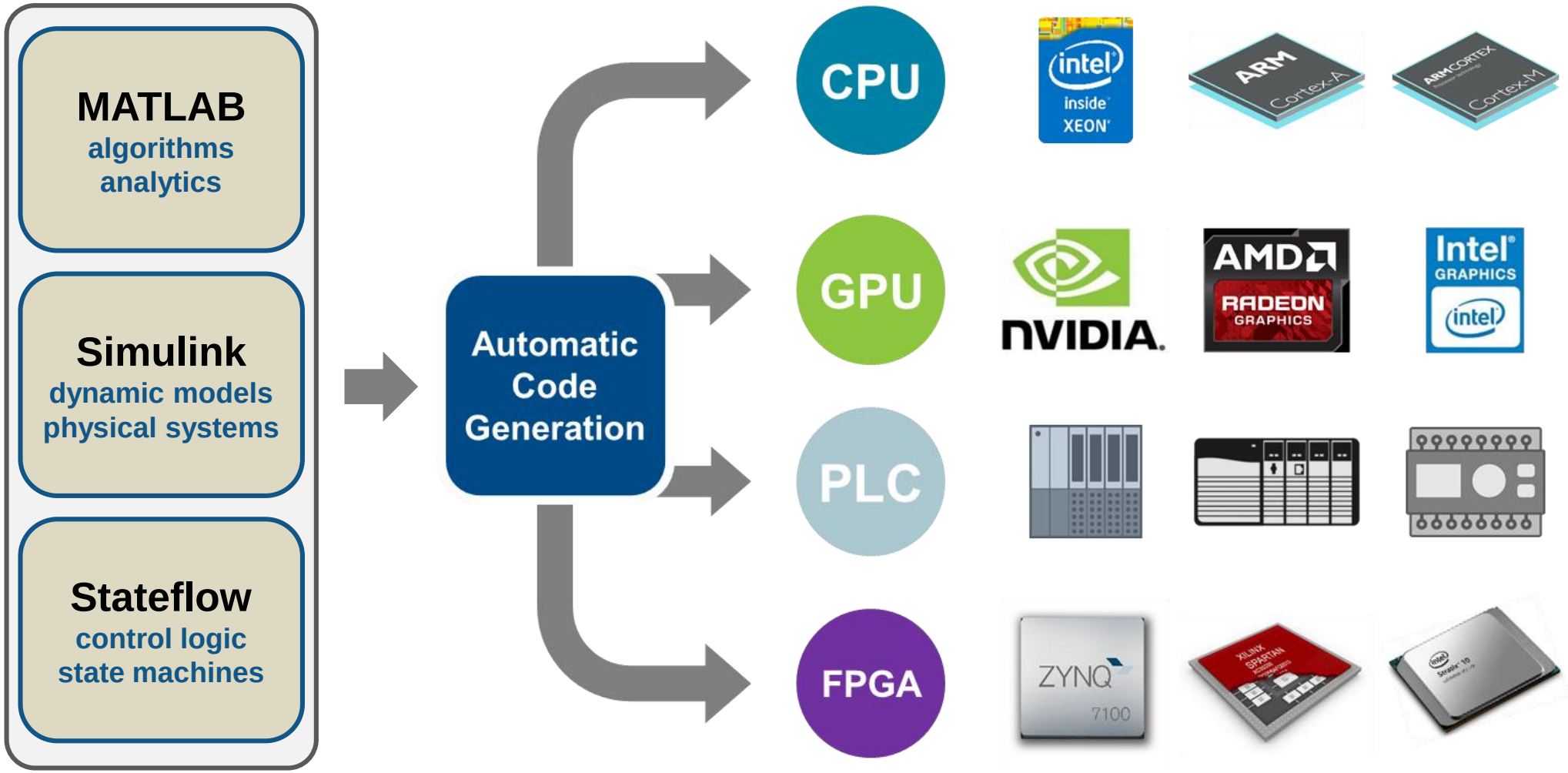


The Steps Associated With Deploying To Hardware Are Complex, But Model-Based Design Is Perfectly Suited To This Application

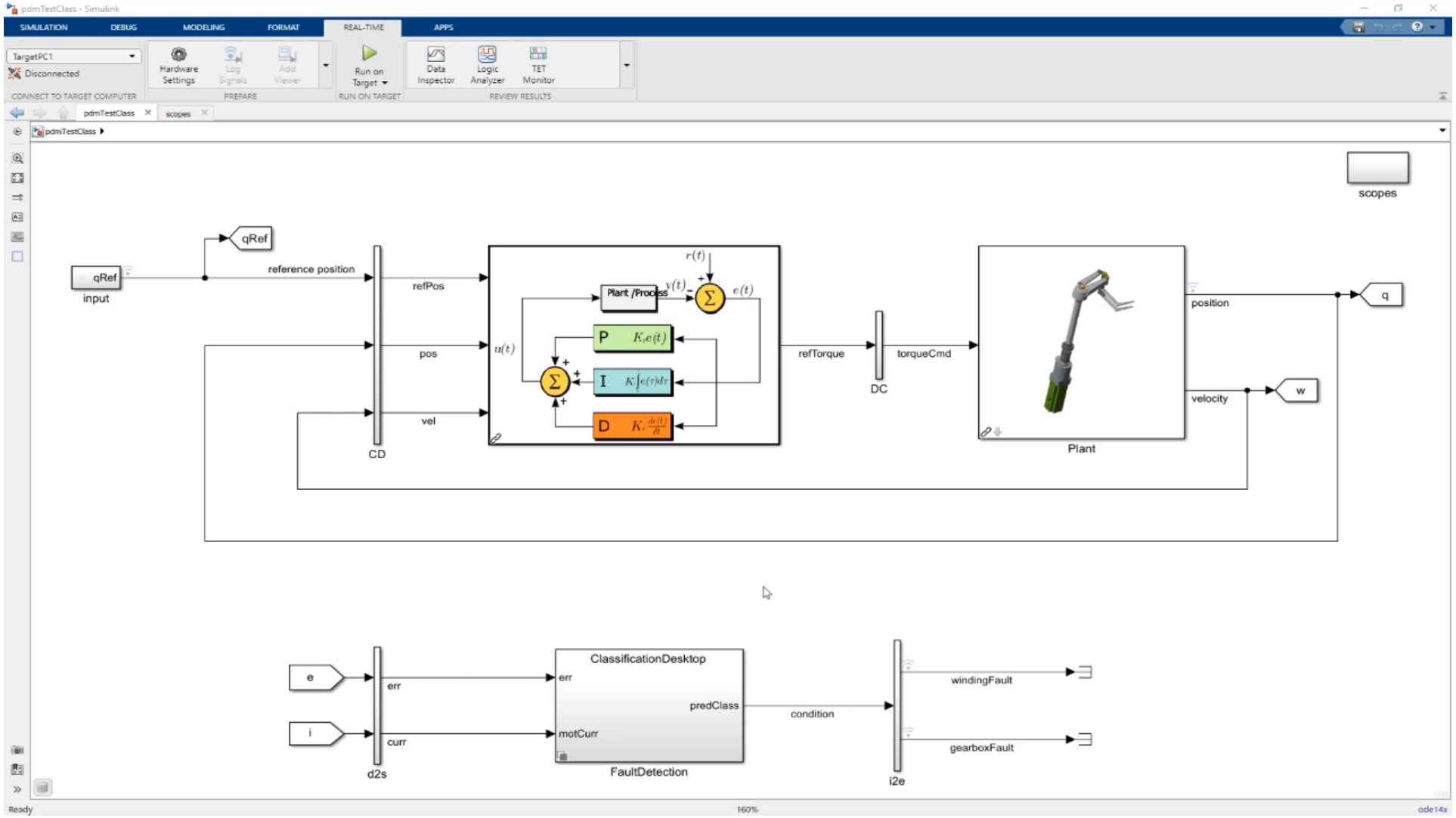
1. Develop algorithm that can run on a resource-constrained edge device
2. Test algorithm in simulation
3. Verify performance using real-time testing
4. Deploy to actual hardware



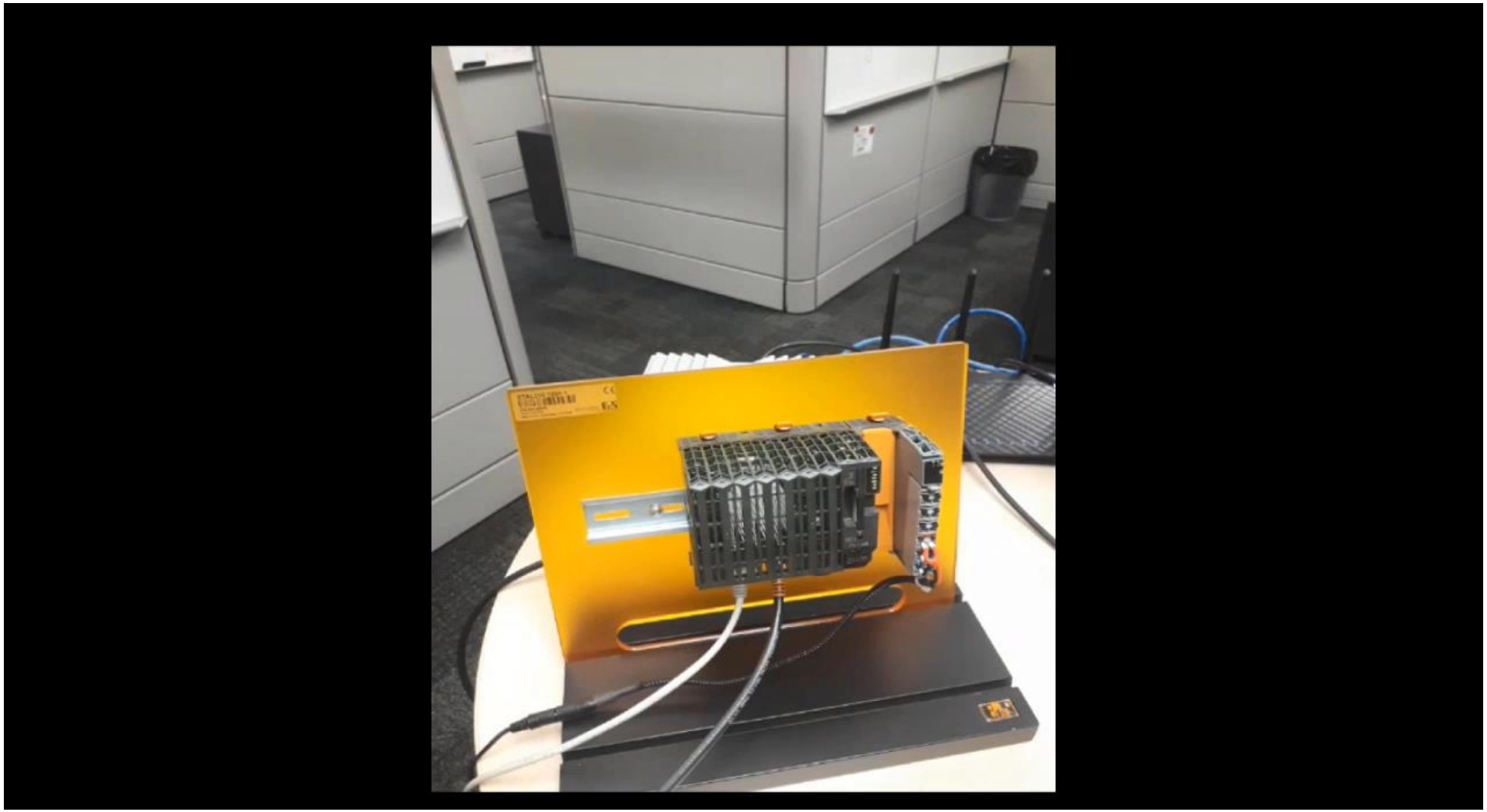
Automatic Code Generation From MATLAB & Simulink Simplifies This Process



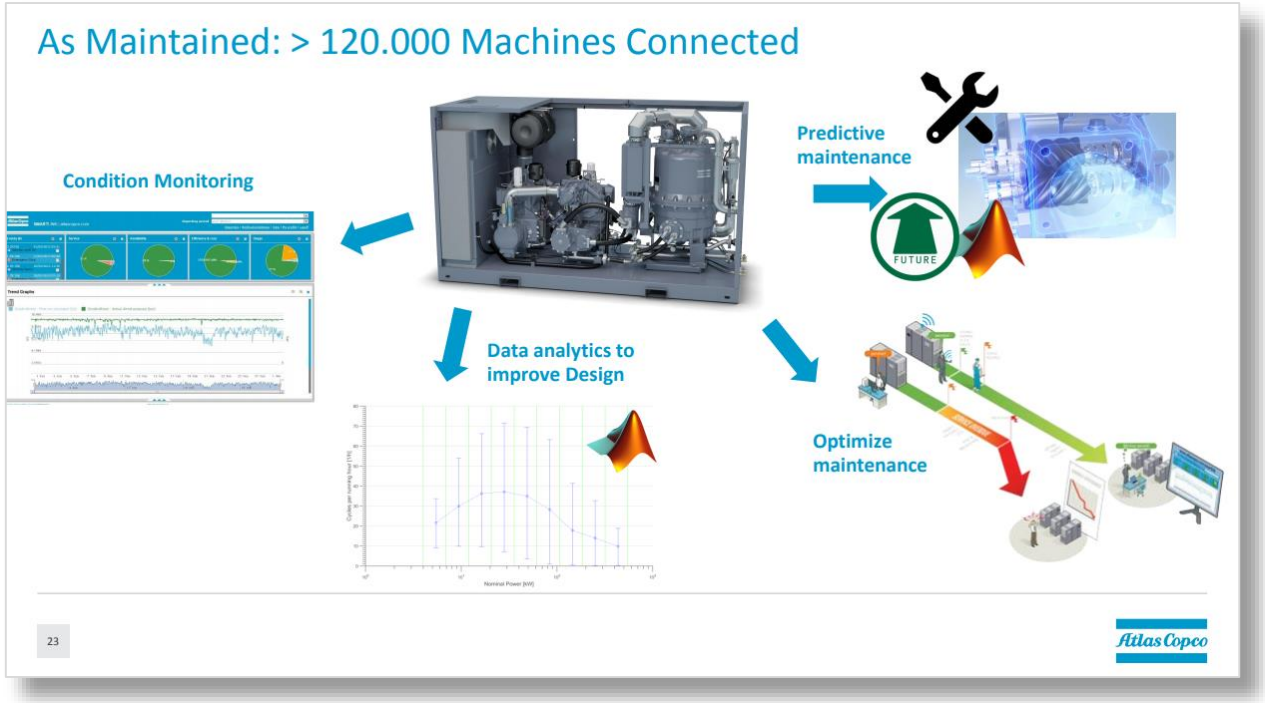
Check If Fault Classification Algorithm Behaves As Expected Using Simulation

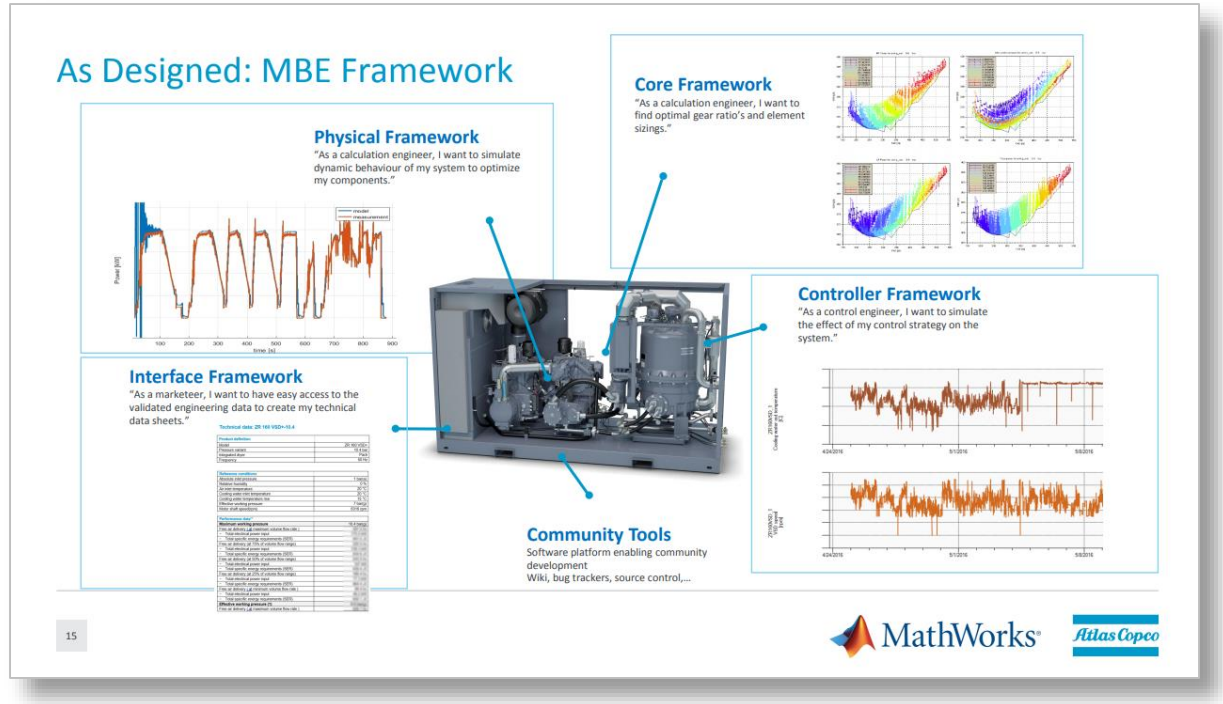


Deploy Algorithm To PLC Using Automatic Code Generation & Verify Performance Using Real-Time Testing



Atlas Copco Is Using Model Based Engineering and Digital Twins For Minimizing Cost





[MATLAB Expo Talk Link]

End Users Require Easy Access To Actionable Information. Dashboards Integrated With IT & OT Systems Make This Possible

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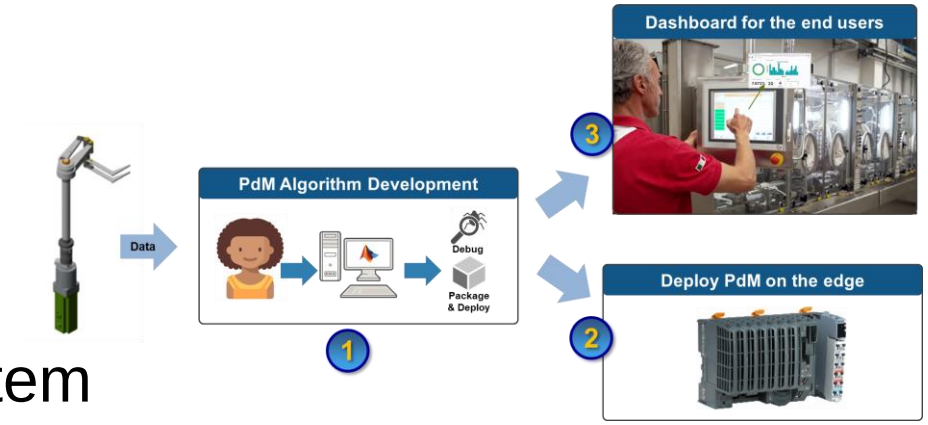
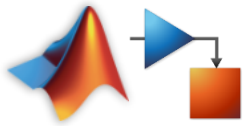
3. Algorithm Deployment to Azure-based IT System
   - MATLAB Compiler & MATLAB Production Server



Building Such A System Requires 3 Different Skill Sets: Algorithm Development, Data Visualization, & Data Management

Engineer & Data Scientist

Develops algorithms in MATLAB and Simulink



Dashboard Builder

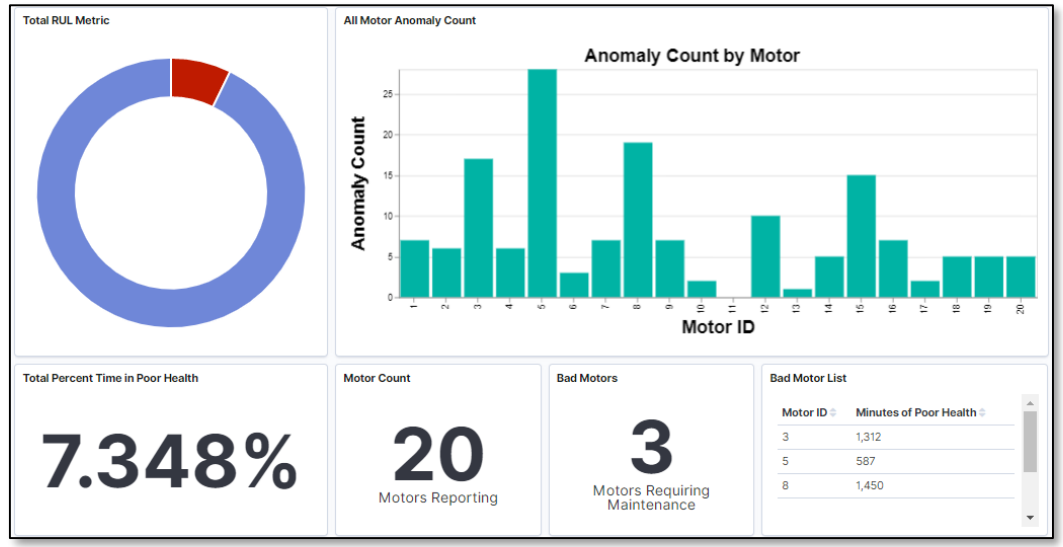
Designs visualization for plant operator

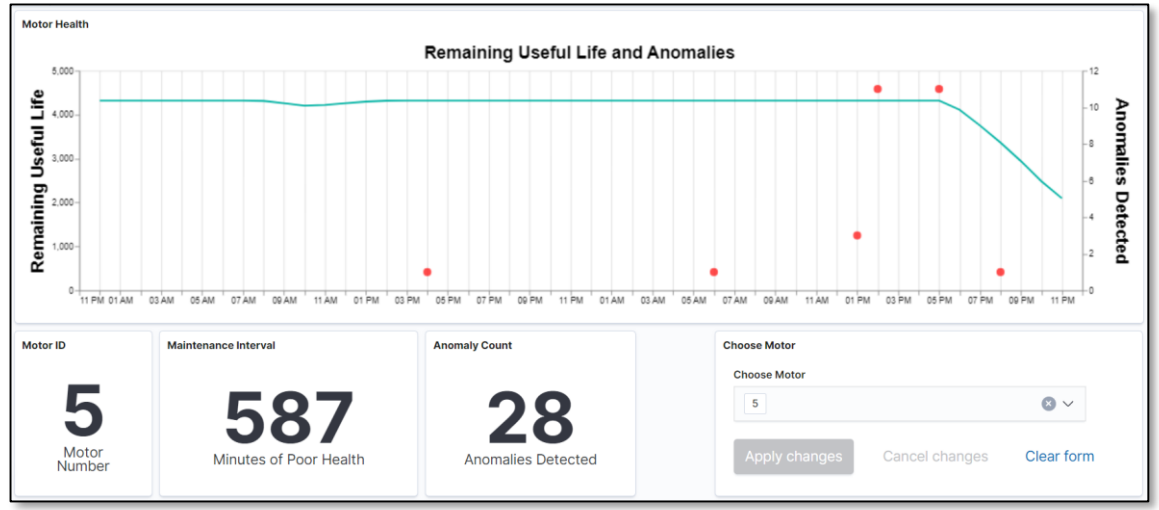
kibana

System Architect

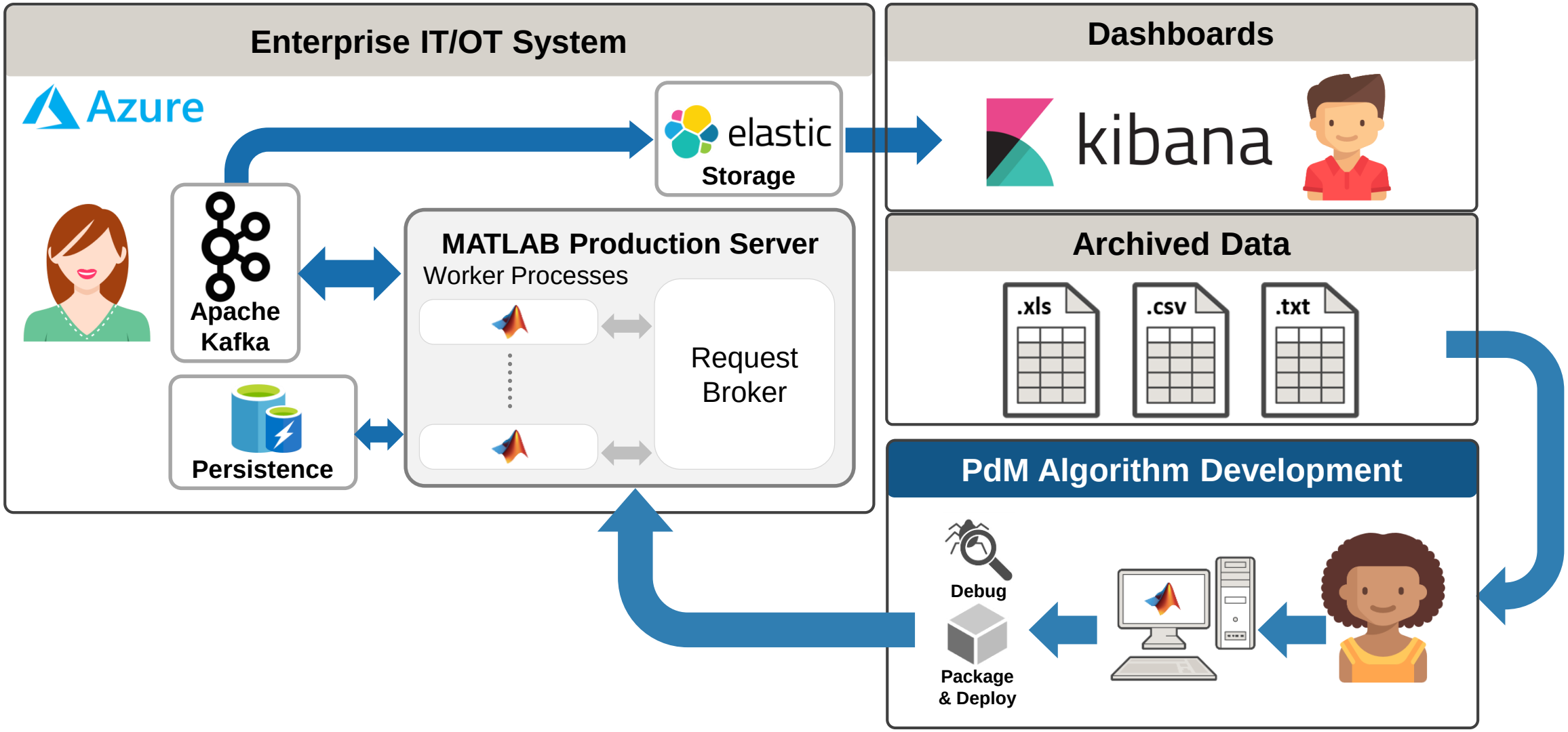
Deploys and operationalizes model on Azure cloud

Azure

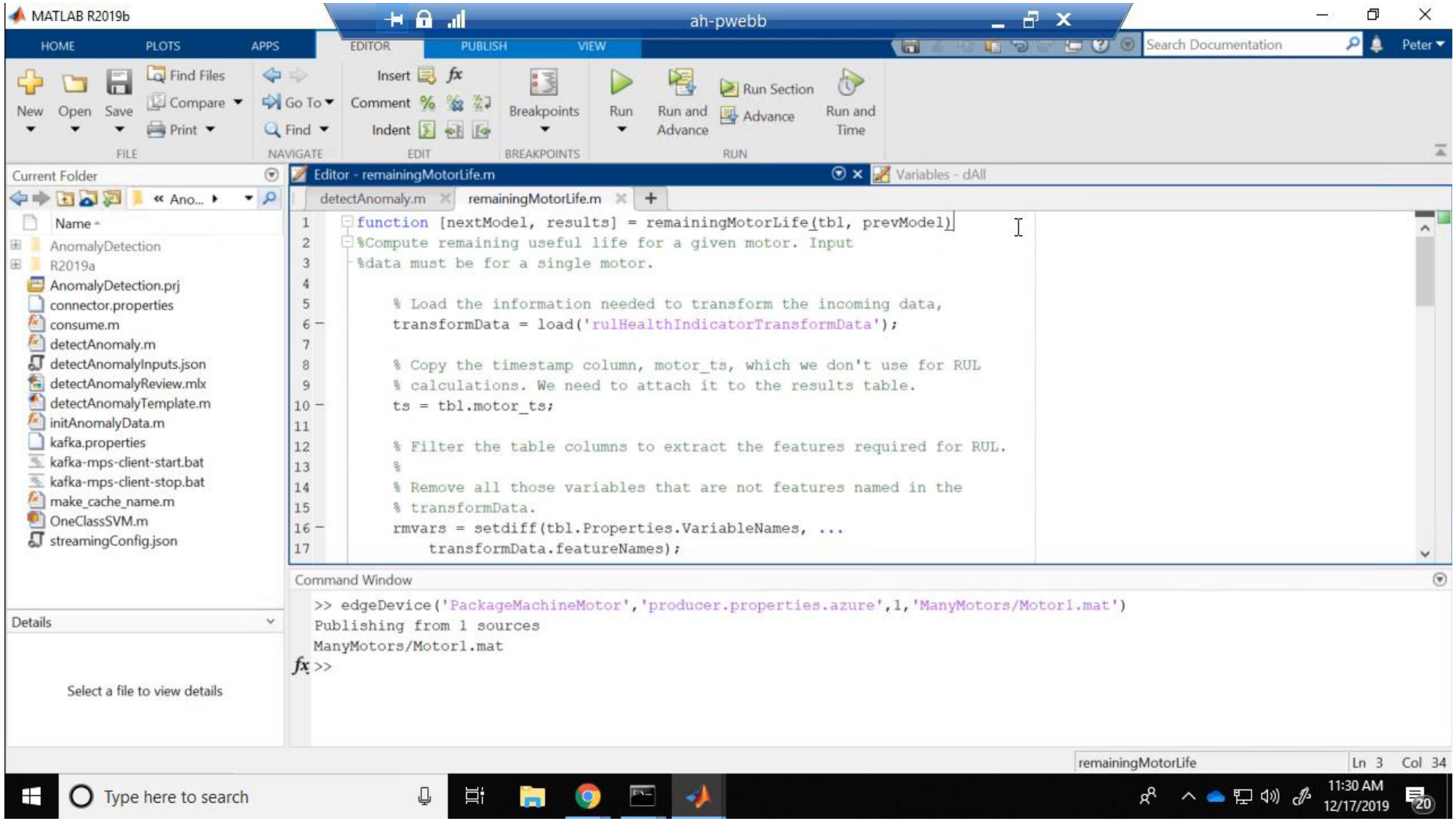




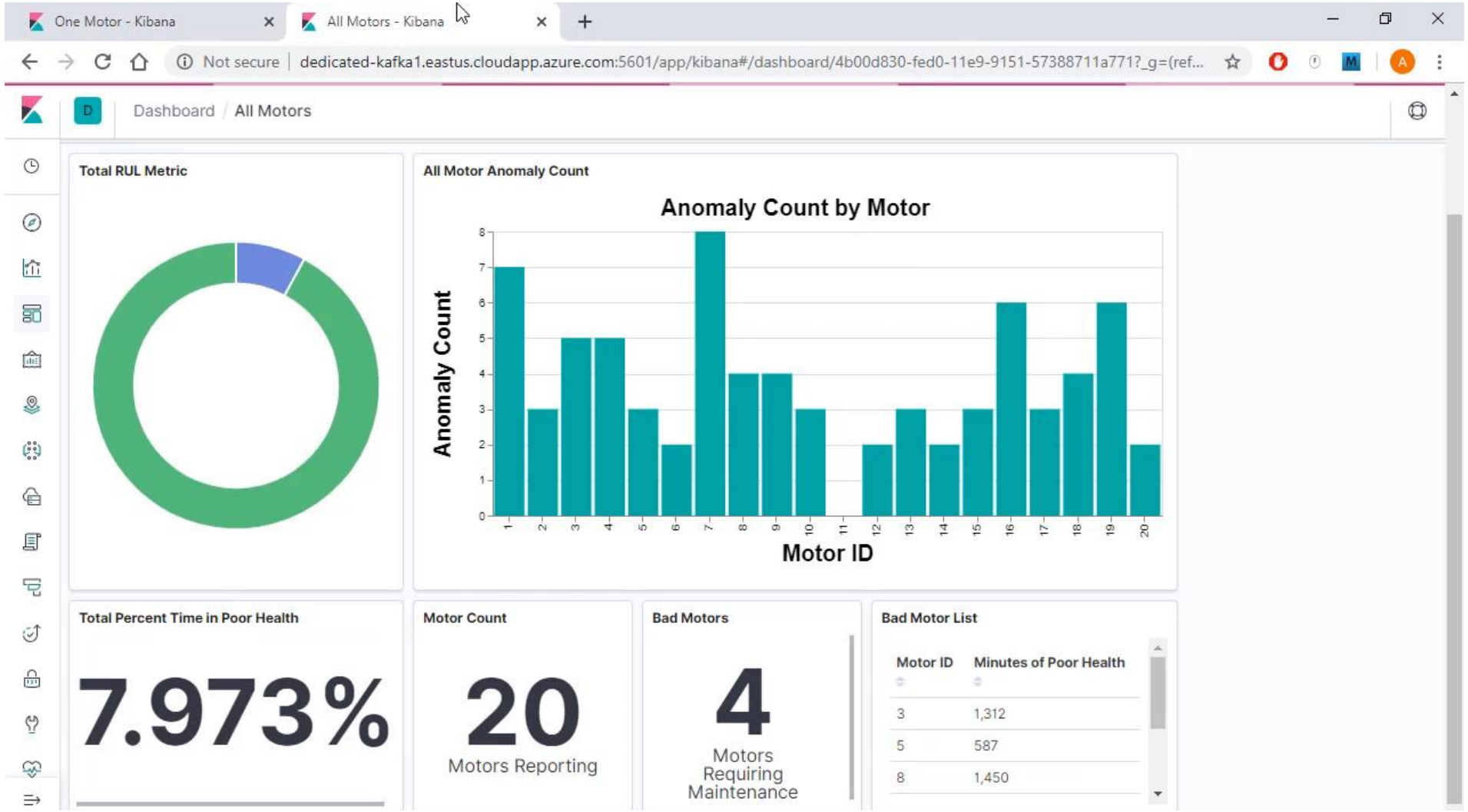
Engineers & Data Scientists Can Package Their Algorithms As Standalone Executables Or Shareable Libraries Using MATLAB



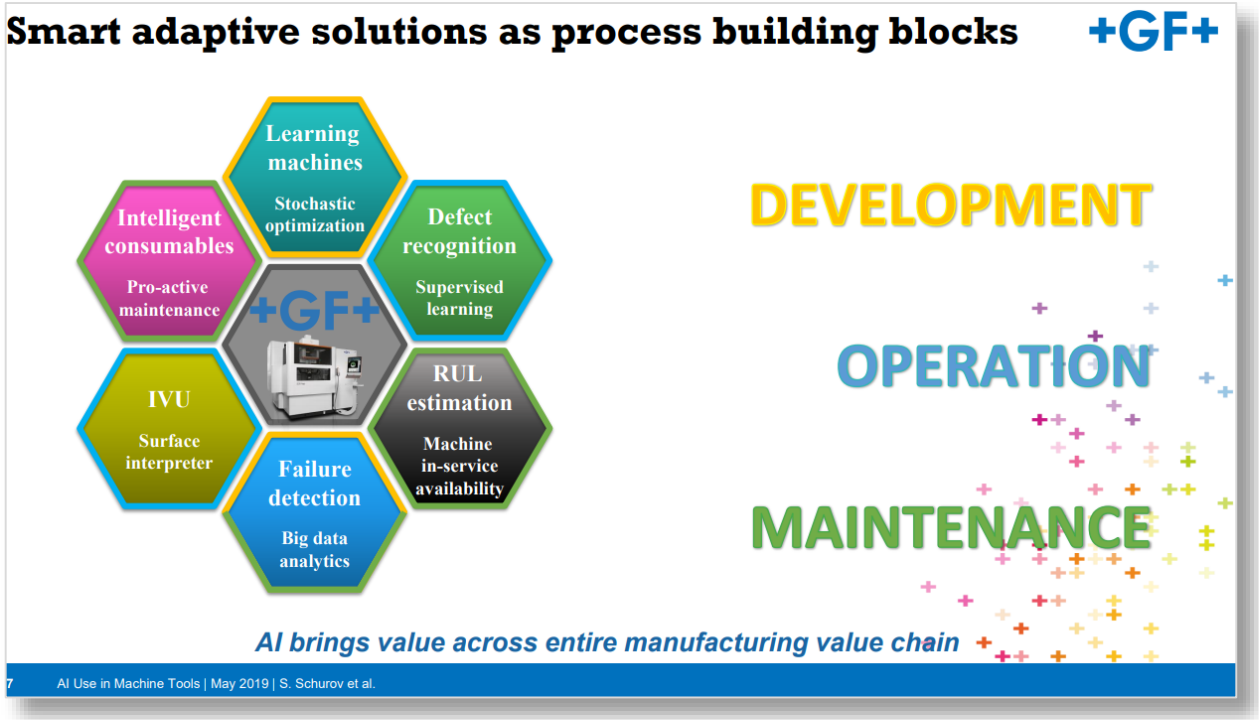
Well Defined Interfaces For Cloud Architectures & One-Click Creation of Cloud-Deployable Applications

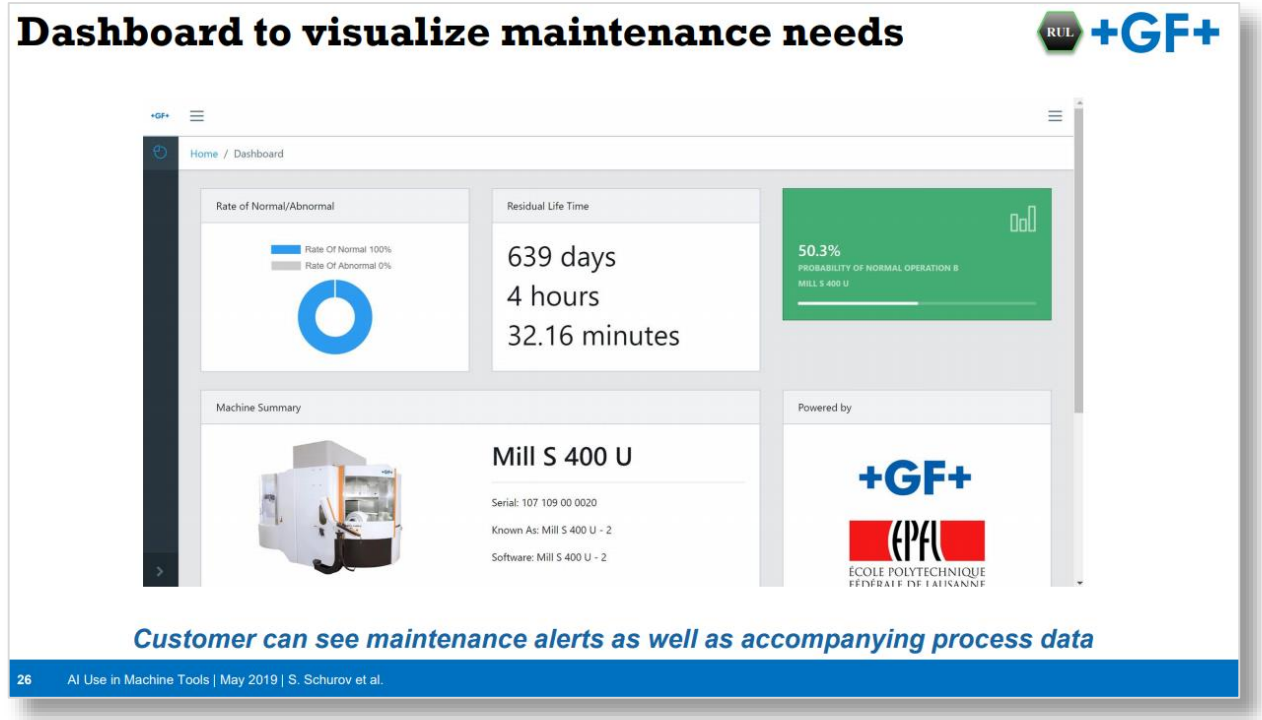


Integrate MATLAB Analytics For Predictive Maintenance With Your Dashboards & Existing IT/OT Infrastructure



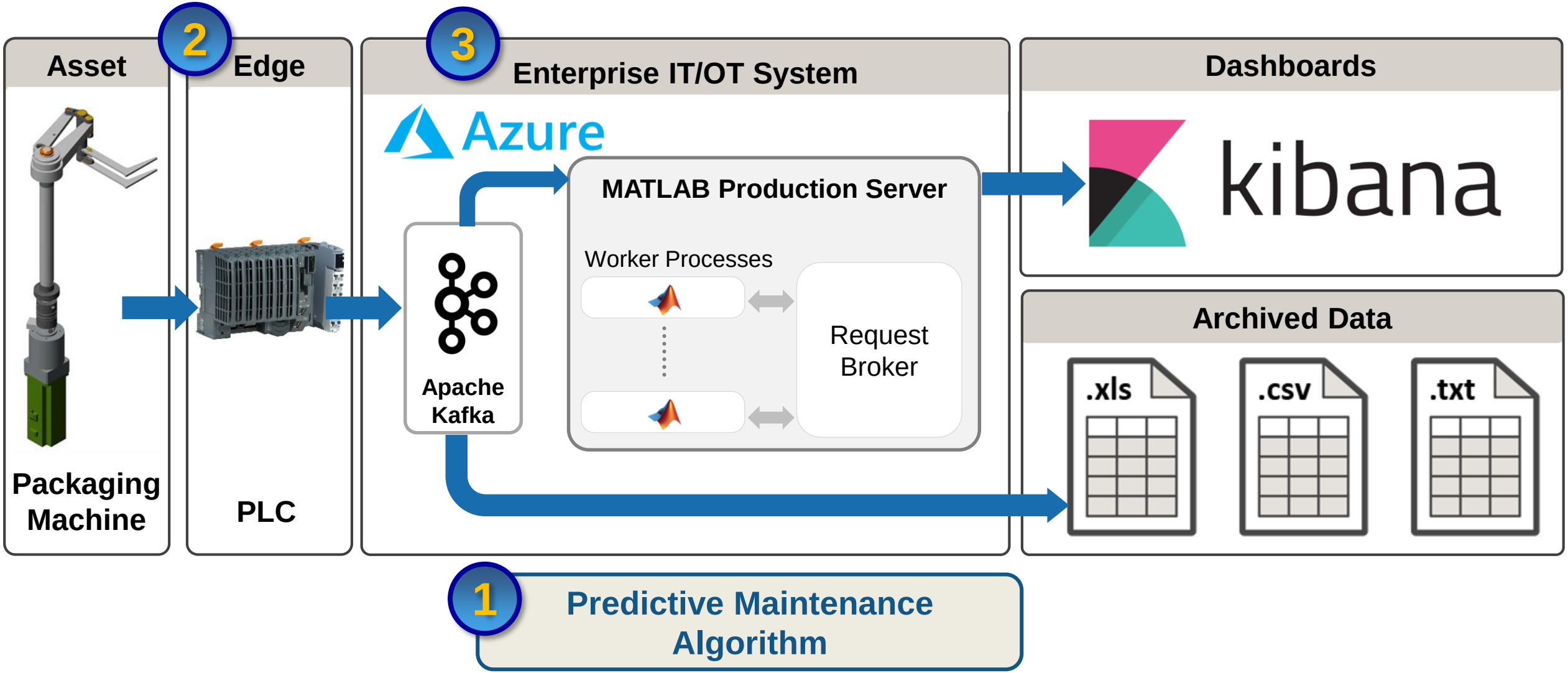
GF Machining Solutions Built Condition Monitoring Dashboards To Visualize Maintenance Needs & Predict Failures





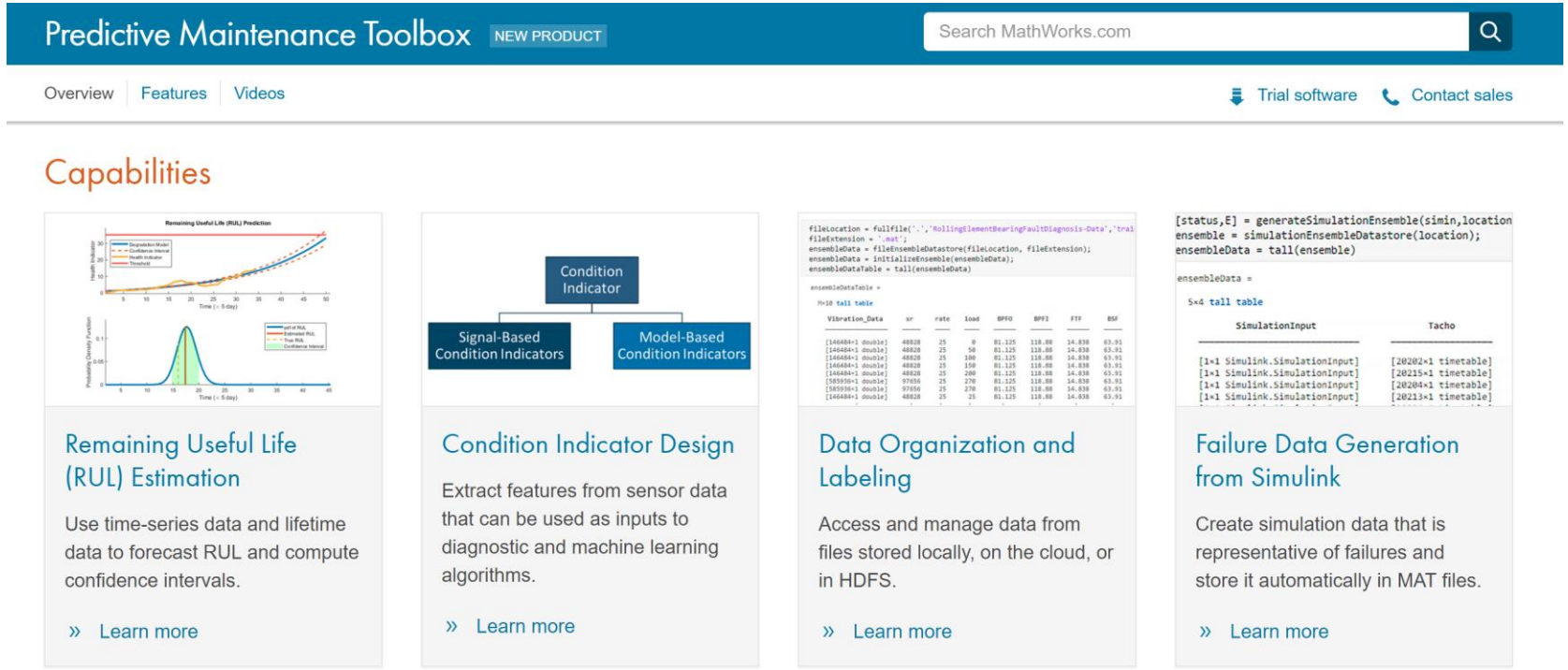
[MATLAB Expo Talk Link]

Today, We Will Demonstrate How To Deploy A Predictive Maintenance Algorithm To The Edge & Enterprise IT/OT Systems



MathWorks can help you get started TODAY

- Examples
- Documentation
- Tutorials & Workshops
- Tech Talk Series



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- 144% average increase in competence

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- 96% of attendees recommend to others

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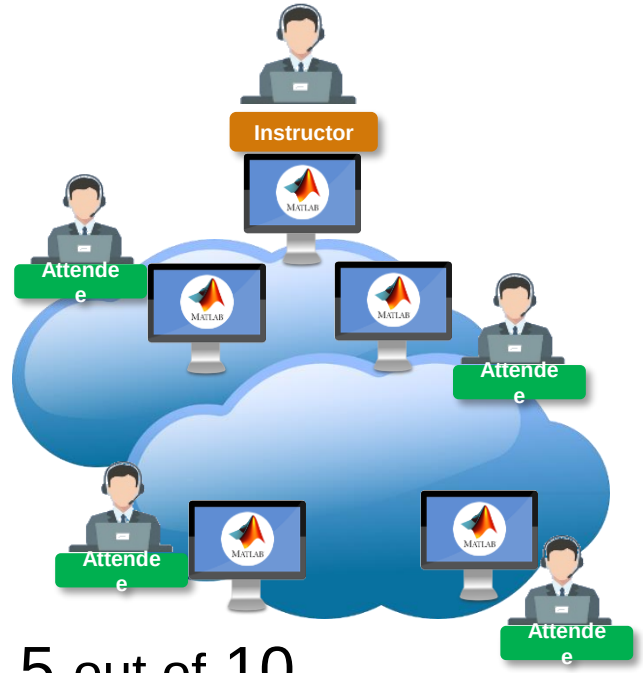
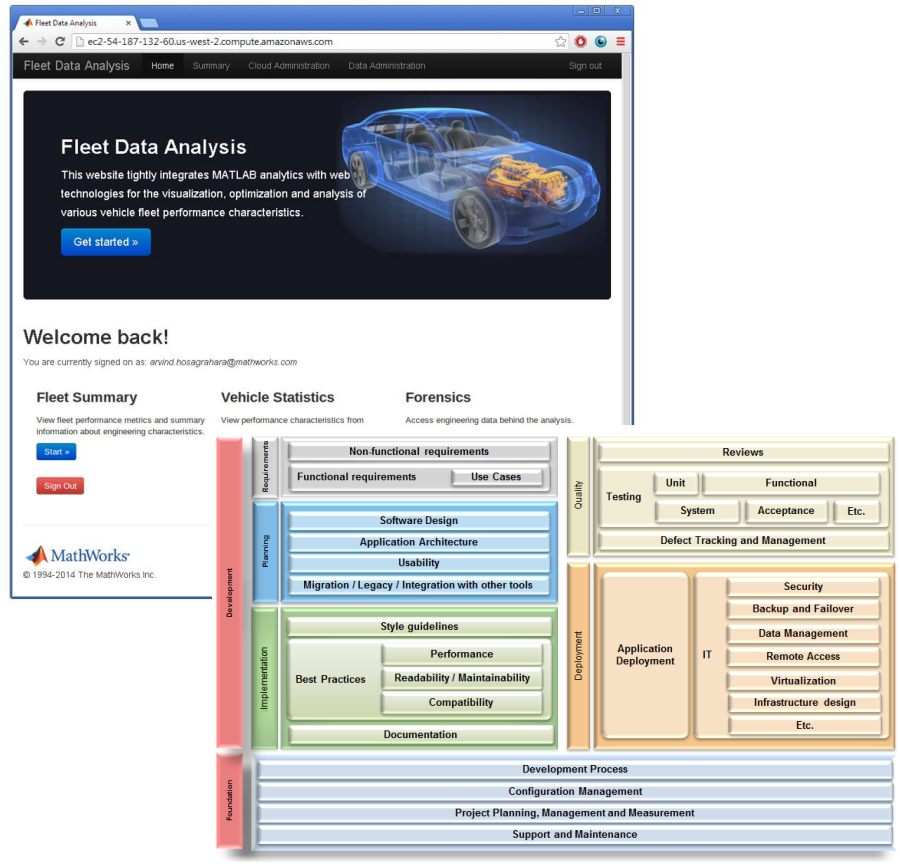


"I attended two online trainings hosted by MathWorks. I was impressed with the virtual learning format. The instructor did an outstanding job presenting course material and facilitating attendee understanding."

Matt Fisher, Ultradent Products, USA

MathWorks Services

- Consulting – Engineering AI
  - Integration
  - Data analysis/visualization
  - Unify workflows, models, data



Consulting for Predictive Maintenance
https://www.mathworks.com/services/consulting/proven-solutions/predictive-maintenance.html

Our Solution Addresses Every Challenge By Providing a Workflow That Spans Algorithm Development & Deployment

- Explore and automate feature extraction & machine learning tasks

- Target edge devices through C/C++ codegen
- Integrate with on-premise or cloud-based Enterprise IT/OT systems

- Generate failure data from Simulink & Simscape models of machines

- Get started using Reference Examples
- Work with our Consulting group to scope & define a project

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Q&A