

MATLAB EXPO 2017

Predictive Maintenance with MATLAB & Simulink

Mehernaz Savai

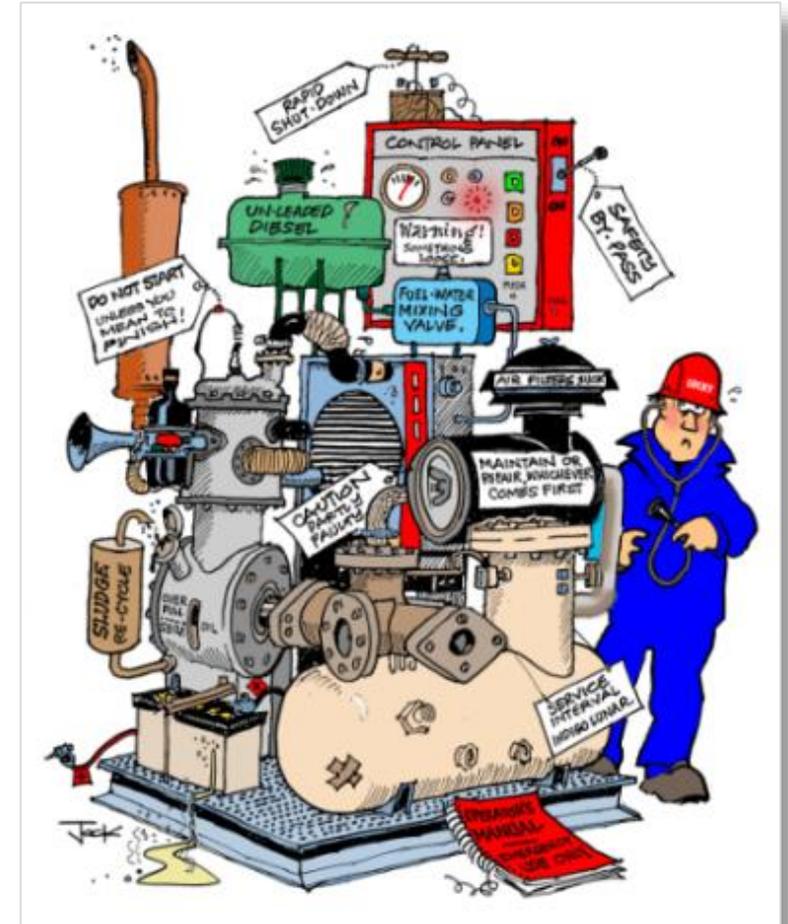
Predictive Maintenance

What is Predictive Maintenance?

- Maintenance technique that reduces unnecessary maintenance and eliminates unplanned downtime

What does a Predictive Maintenance solution do?

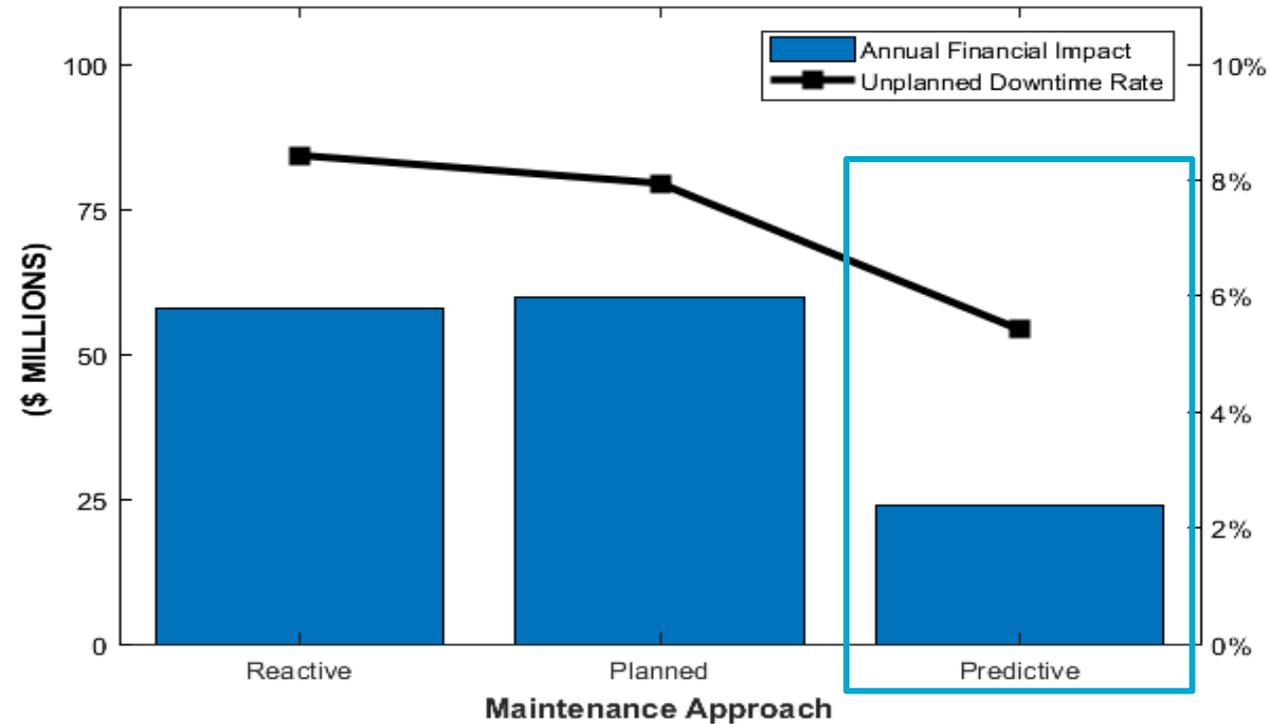
- Uses historical data + sensor data to predict Time-to-Failure or Remaining Useful Life
- Relay this information to maintenance engineers, operators, and plant managers



Source: Tensor Systems

Why is Predictive Maintenance Important?

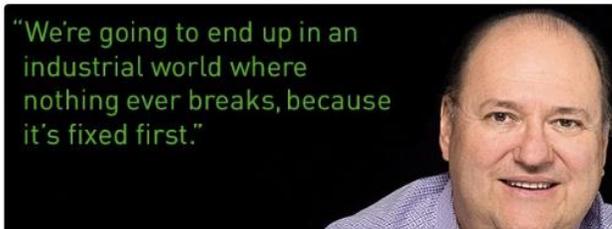
- Improved operating efficiency
- New revenue streams
- Competitive differentiator



Why is Predictive Maintenance Important?

- Improved operating efficiency

Bill Ruh Retweeted
GE Digital @GE_Digital · Feb 1
 What does the future of the #IIoT look like? Our CEO @BillRuh_GE explains in this new interview: stratz.to/gASk308yoP0



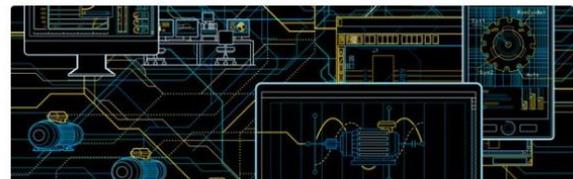
The Thought Leader
Bill Ruh
 strategy+business
 Bill Ruh, CEO

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



- New revenue streams

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



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



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

- Competitive differentiator

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



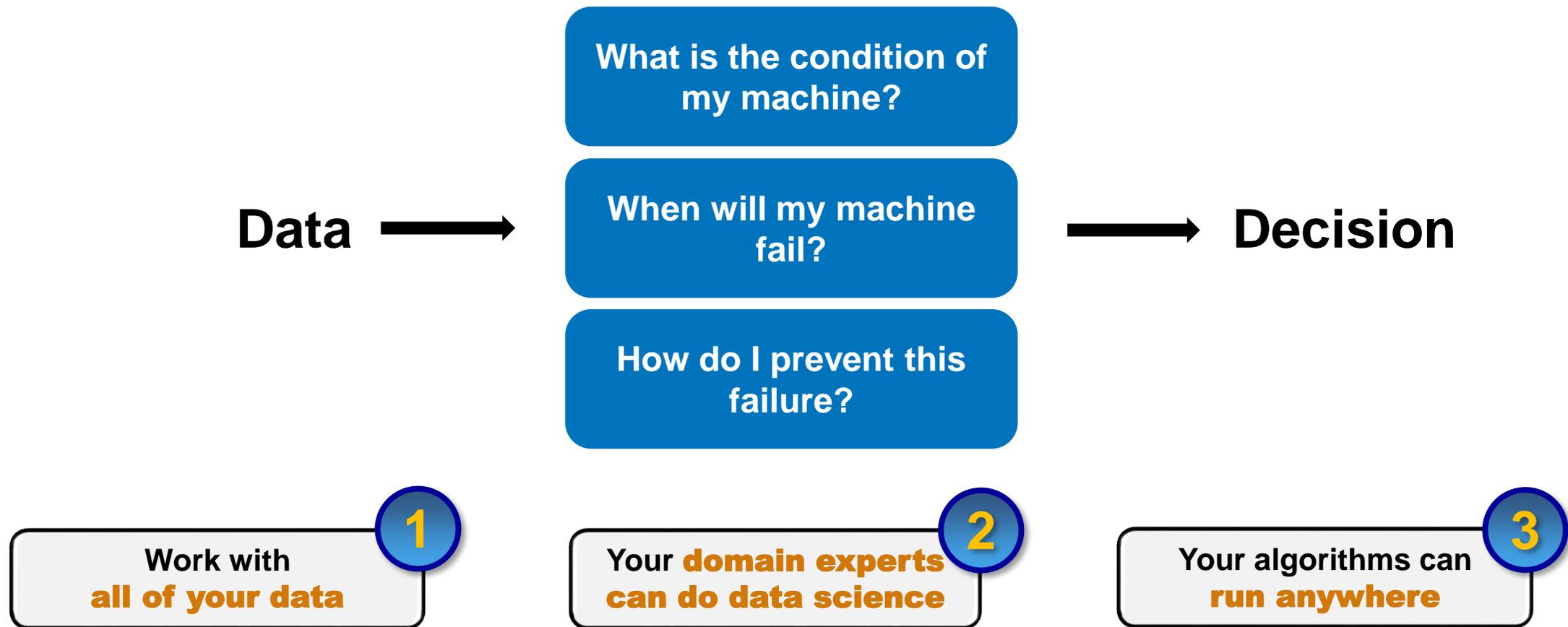
Software Innovations @BoschSI · Jan 31
 How to develop a #DataAnalytics tool for #PredictiveMaintenance in 1 week? youtube.com/watch?v=9mas0b... #IIoT #Industry40



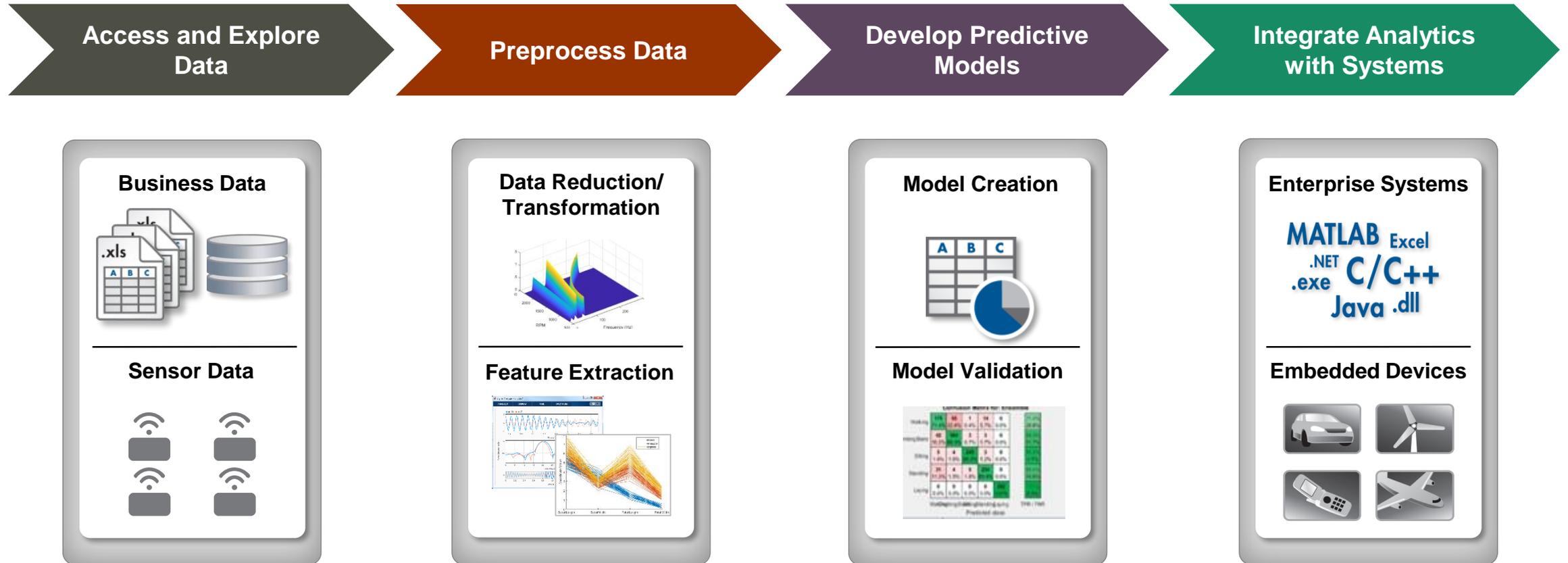
How to develop a data analytics tool in 1 week (Part 1)
 A team of data scientists, manufacturing & software experts at Bosch Software Innovations developed a data analytics tool for predictive maint...
youtube.com

What should a Predictive Maintenance Algorithm do?

Turn large volumes of complex data into decisions



Predictive Maintenance Algorithm Workflow



Access and Preprocess Data



Business Data

Sensor Data

1

**Data Reduction/
Transformation**

Feature Extraction

Model Creation

Model Validation

Enterprise Systems

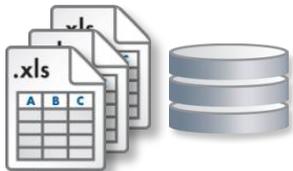
MATLAB Excel
.NET C/C++
.exe Java .dll

Embedded Devices

Access and Preprocess Data

Access and Explore Data

Business Data



Sensor Data

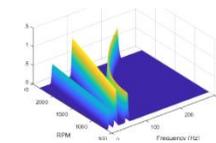


Challenges

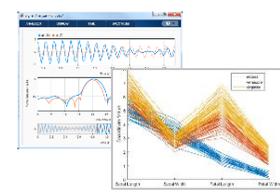
- I have too much data to handle easily
- I don't have enough data
- I have no data
- I have too many data types and data sources
- My data is too messy

Preprocess Data

Data Reduction/Transformation



Feature Extraction

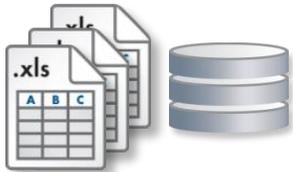


Access and Preprocess Data

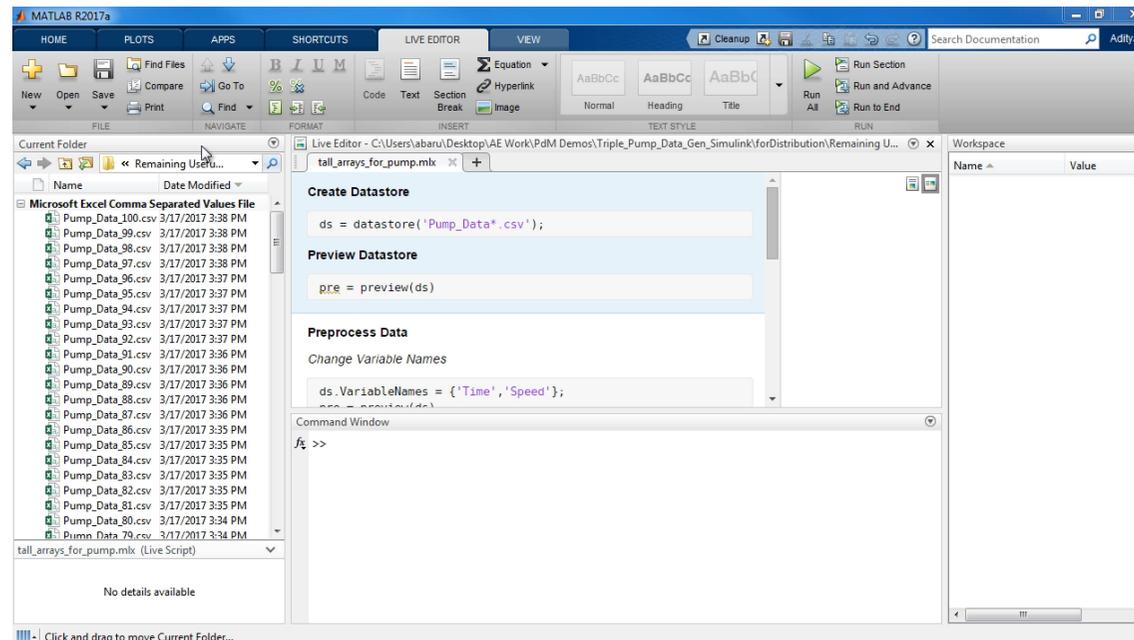
Access and Explore Data

Preprocess Data

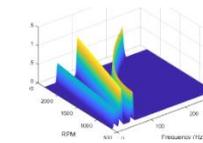
Business Data



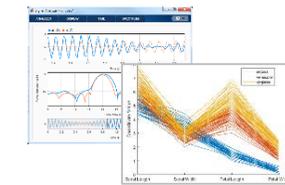
Sensor Data



Data Reduction/
Transformation



Feature Extraction

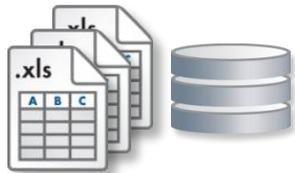


Access and Preprocess Data

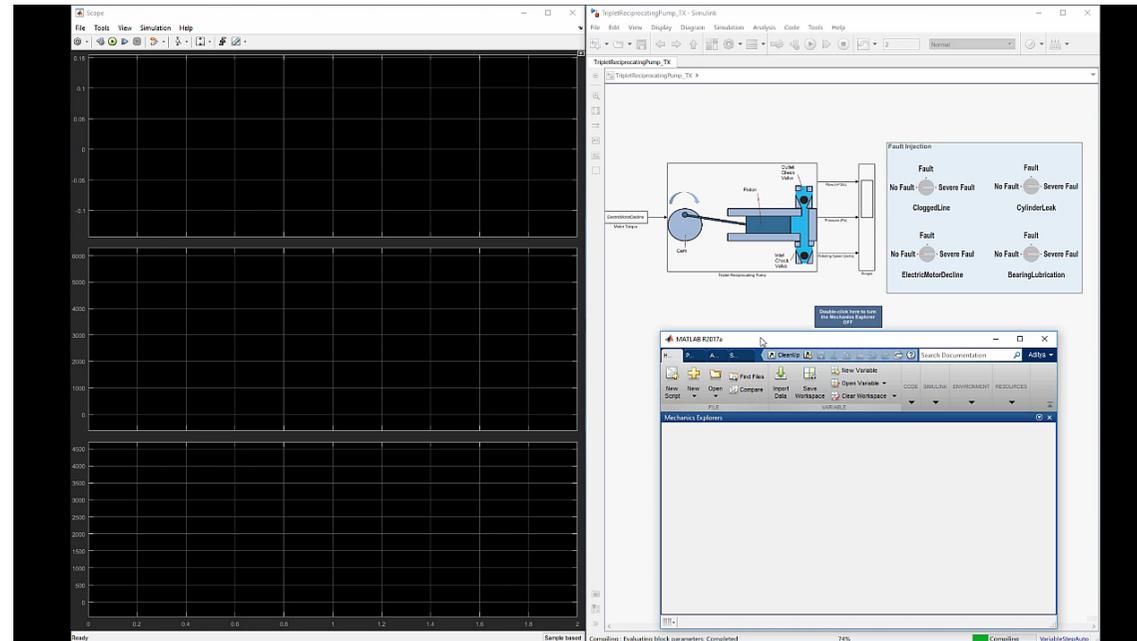
Access and Explore Data

Preprocess Data

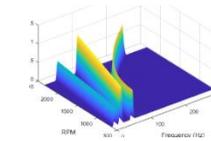
Business Data



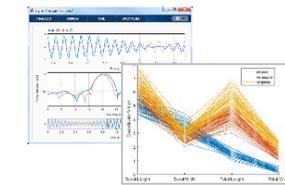
Sensor Data



Data Reduction/
Transformation



Feature Extraction



Access and Preprocess Data

Access and Explore Data

Business Data

Sensor Data

Find out more:

**2 PM Session: Employing
Simscape to model electro-
mechanical systems in Simulink**

Preprocess Data

**Data Reduction/
Transformation**

Feature Extraction

Access and Preprocess Data

1
Work with **all of your data**

Access and Explore Data

Preprocess Data

Business Data

Sensor Data

Databases

Images

HDFS

Files

Signals

Videos

- Point and click tools to access variety of data sources
- High-performance environment for big data
- Built-in algorithms for data preprocessing

Data Reduction/Transformation

Feature Extraction

Build Predictive Models



Business Data

Sensor Data

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**Data Reduction/
Transformation**

Feature Extraction

2

Model Creation

Model Validation

Enterprise Systems

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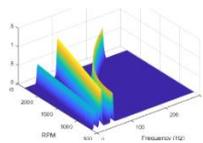
Embedded Devices

Build Predictive Models

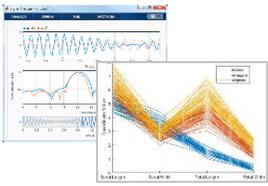
Preprocess Data

Develop Predictive Models

**Data Reduction/
Transformation**



Feature Extraction



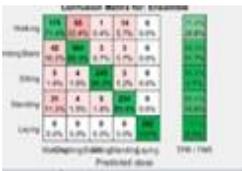
Challenges

- I need to incorporate my domain knowledge
- I need to extract and verify health indicators
- I lack machine learning experience
- I have deadlines to meet

Model Creation



Model Validation



Build Predictive Models

Preprocess Data

Develop Predictive Models

Data Reduction/Transformation

Feature Extraction

```

1  Script_2_data_analyze_individual_solo.m
2  %% Setup
3  clear;
4  clc;
5  load('data_cell_14-Feb-2017_12_53_49.mat');
6
7  data_cell = flipud(data_cell);
8  c_1 = [0 0.4470 0.7410];
9  num=100;
10 data_freq_f = cell(100,1);
11
12 %% Get Healthy Run Data
13
14 tout = data_healthy(:,1);
15 yout = data_healthy(:,2);
    
```

Command Window
fx >>

Model Creation

Model Validation

	RMSE	MAE	MAPE	MAPE	MAPE
Modeling	0.000	0.000	0.000	0.000	0.000
Modeling	0.000	0.000	0.000	0.000	0.000
Modeling	0.000	0.000	0.000	0.000	0.000
Modeling	0.000	0.000	0.000	0.000	0.000
Modeling	0.000	0.000	0.000	0.000	0.000

Build Predictive Models

2

Your domain experts can do data science

Preprocess Data

Data Reduction/Transformation

Feature Extraction

Apps

MATLAB

```

%% Generalized Linear Model - Logistic Regression
gin = GeneralizedLinearModel_fit(utrain,double(utrain-1),...
    'linear','Distribution','binomial','link','logit');

%% Discriminant Analysis
da = ClassificationDiscriminant_fit(utrain,utrain,...
    'discrimtype','quadratic');

%% Classification Using Nearest Neighbors
knn = ClassificationKNN_fit(utrain,utrain,...
    'nearest','nearest');
    
```

Simulink

Develop Predictive Models

Model Creation

Model Validation

- Easy to use apps across multiple domains
- Documentation, examples, and videos to get started
- Automatic MATLAB code generation

Deploy and Integrate



Business Data

Sensor Data

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**Data Reduction/
Transformation**

Feature Extraction

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Model Creation

Model Validation

3

Enterprise Systems

MATLAB Excel
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.exe Java .dll

Embedded Devices

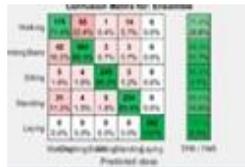
Deploy and Integrate

Develop Predictive Models

Model Creation



Model Validation



Challenges

- I have multiple end users – plant managers, operations analysts, maintenance staff, etc.
- I have to allow access through different target platforms
- I need to scale to meet production needs
- I need to reduce bandwidth consumption

Integrate Analytics with Systems

Enterprise Systems

MATLAB Excel
 .NET C/C++
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Embedded Devices



Deploy and Integrate

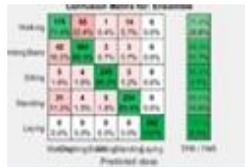
Develop Predictive Models

Integrate Analytics with Systems

Model Creation



Model Validation



Predictive Data Analytics

Home Demand Forecasting Web Service Description Documentation

Predictive Data Analytics
This website tightly integrates MATLAB analytics with web technologies for demonstrating predictive data analytics models in production with live data.

[Get started »](#)

Demand Forecasting

Forecast electricity demand for US power grids with live data from ISOs and weather stations using Neural Network models. Forecasts can be compared to past data as well as normal weather. Prediction bands at different confidence intervals also quantify uncertainty in forecast.

[Start »](#)

Web Service Information

Documentation on end points and query parameters for demand forecast web services

[Read more](#)

App Documentation

Documentation of the entire web application and its components

Coming soon!

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Enterprise Systems

MATLAB Excel
.NET C/C++
.exe Java .dll

Embedded Devices



Deploy and Integrate

3
 Your algorithms can **run anywhere**

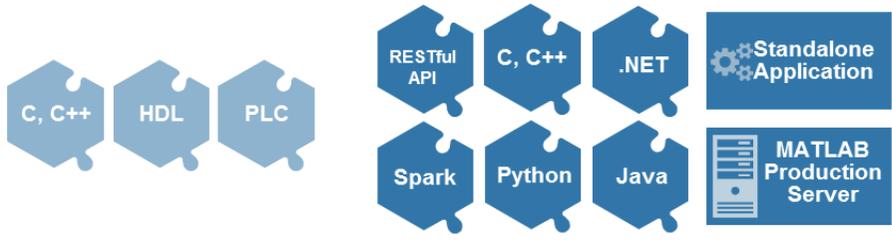
Develop Predictive Models

Model Creation

Model Validation

MATLAB + SIMULINK

Code Generation
Compiled Applications



Embedded Hardware **Enterprise Systems**

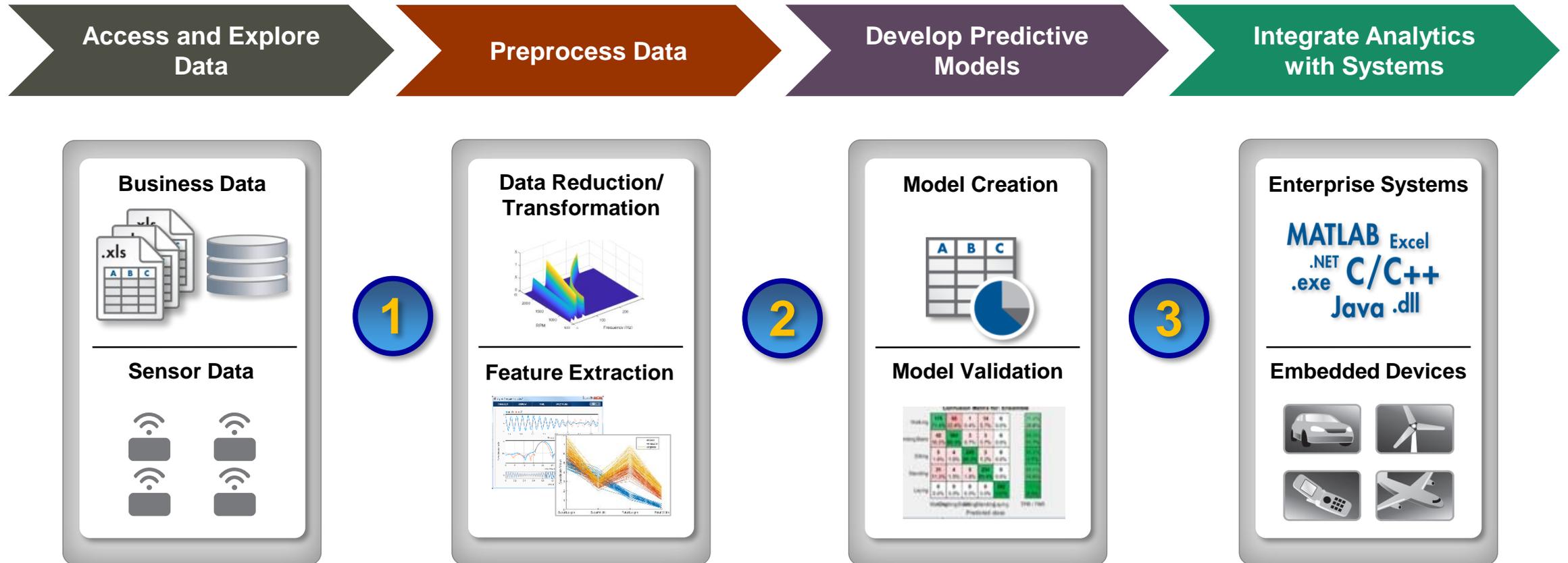
- Royalty-free deployment
- Web services, apps, and cloud platforms
- Computation on smarter edge devices
- Automatic C/C++ code generation

Integrate Analytics with Systems

Enterprise Systems

Embedded Devices

Predictive Maintenance Algorithm Workflow



What does success look like?

Baker Hughes: Pump Health Monitoring System

Challenge

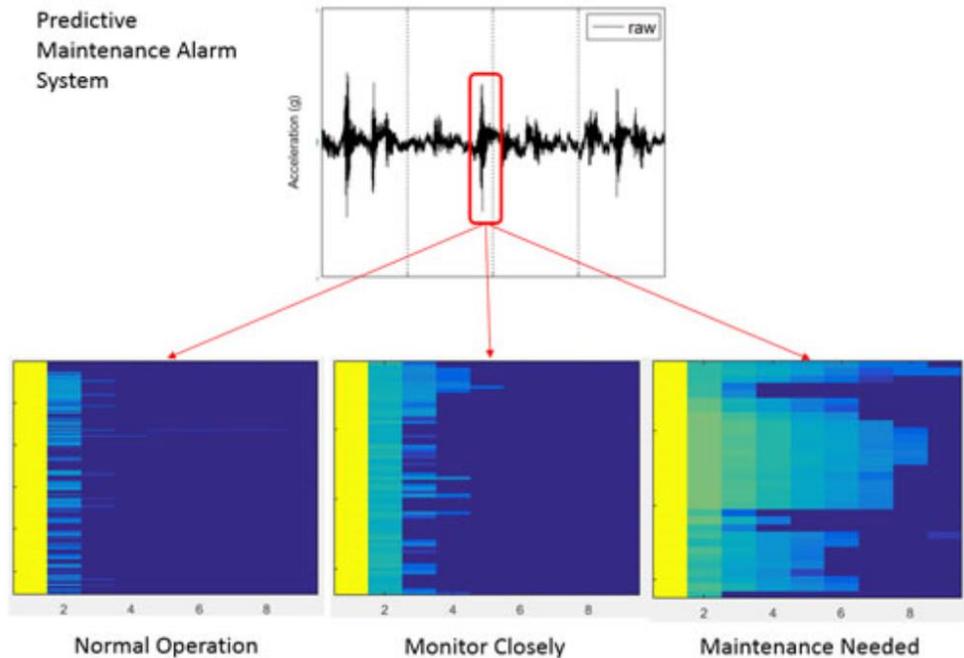
- As many as 20 trucks operate around the clock at a well site
- A truck with a pump failure must be immediately replaced

Solution

- Analyzed a **terabyte of data** collected at 50,000 samples/second
- Performed **FFTs and spectral analysis** to filter large movements of the truck, pump, and fluids
- Best model was a **neural network** using pressure, vibration, and timing sensor data of the valves and valve seats

Results

- Savings of **more than \$10 million** projected
- Development time reduced tenfold



Key Takeaways

1

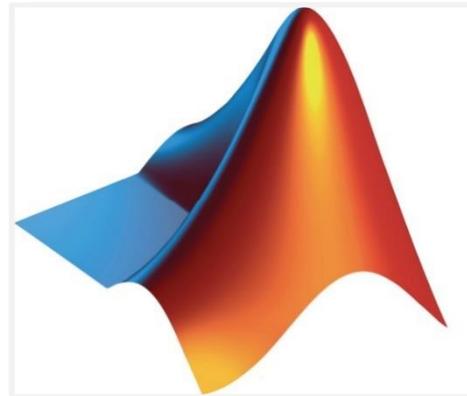
Work with
all of your data

2

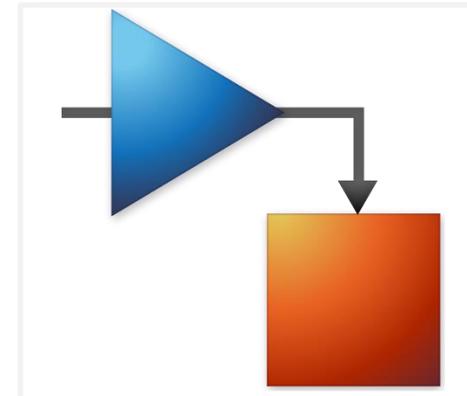
Your **domain experts**
can do data science

3

Your algorithms can
run anywhere



+



Key Takeaways

