

# MATLAB CONFERENCE 2017

## Predictive Maintenance with MATLAB and Simulink

Daryl Ning  
Applications Engineer  
MathWorks Australia



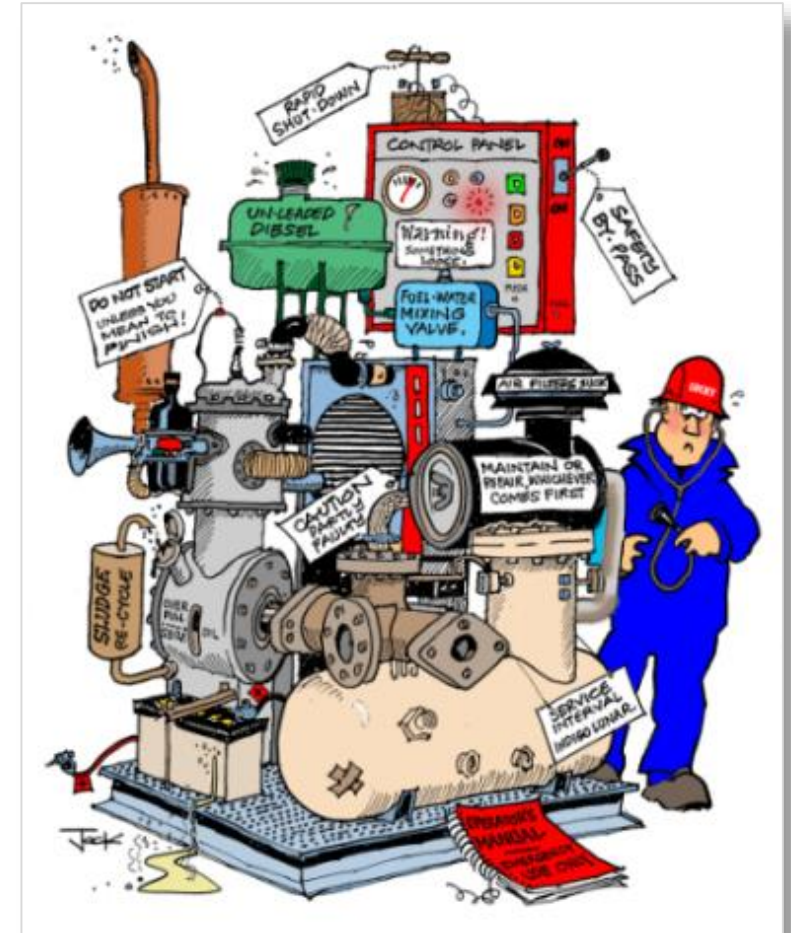
# Predictive Maintenance

Identify and prevent failures before they occur:

- Reduces unnecessary maintenance
- Eliminates unplanned downtime

Consists of:

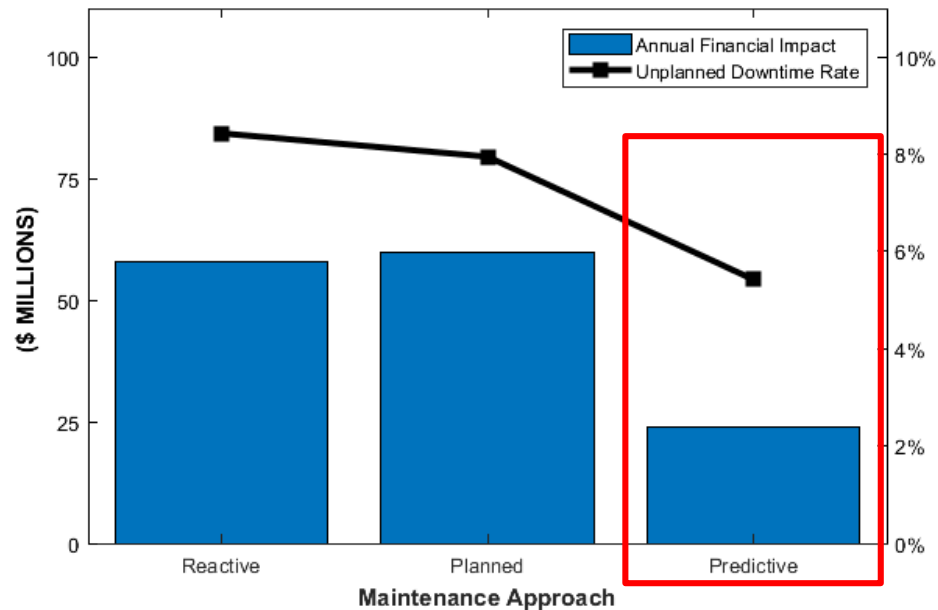
- Algorithms to predict Time-to-Failure or Remaining Useful Life
- Interfaces to communicate information to maintenance crew



Source: Tensor Systems

# Why is Predictive Maintenance Important?

**\$35M Saved**  
**Unplanned downtime rate reduced by 30%**



Source: GE Oil & Gas

- Improved Operating Efficiency
- New Revenue Streams
- Competitive Differentiator

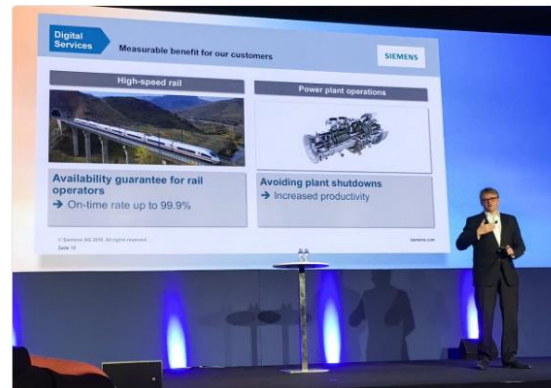
# Industry Agrees that Predictive Maintenance is Important

- 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: [stratbz.to/gASk308yoP0](http://stratbz.to/gASk308yoP0)



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



**Measurable benefit for our customers**

High-speed rail	Power plant operations
Availability guarantee for rail operators → On-time rate up to 99.9%	Avoiding plant shutdowns → Increased productivity

- New revenue streams

**ABB Global** @ABBgroupnews · Follow  
 A game changer that opens the door to predictive maintenance [ow.ly/4nc2TT](http://ow.ly/4nc2TT) #IIoT #HM16



**SAP IoT** @SAP\_IoT · Follow  
 John Deere uses machine alerts using #telematics for predictive maintenance and to lower downtime of assets [v3.co.uk/v3-uk/news/234](http://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](http://v3.co.uk)

- Competitive differentiator

**Intel IoT** @IntelIoT · Follow  
 #DYK predictive maintenance can cut yield losses by 25%? Major benefits of #IIoT: [intel.ly/2dg7Otm](http://intel.ly/2dg7Otm)



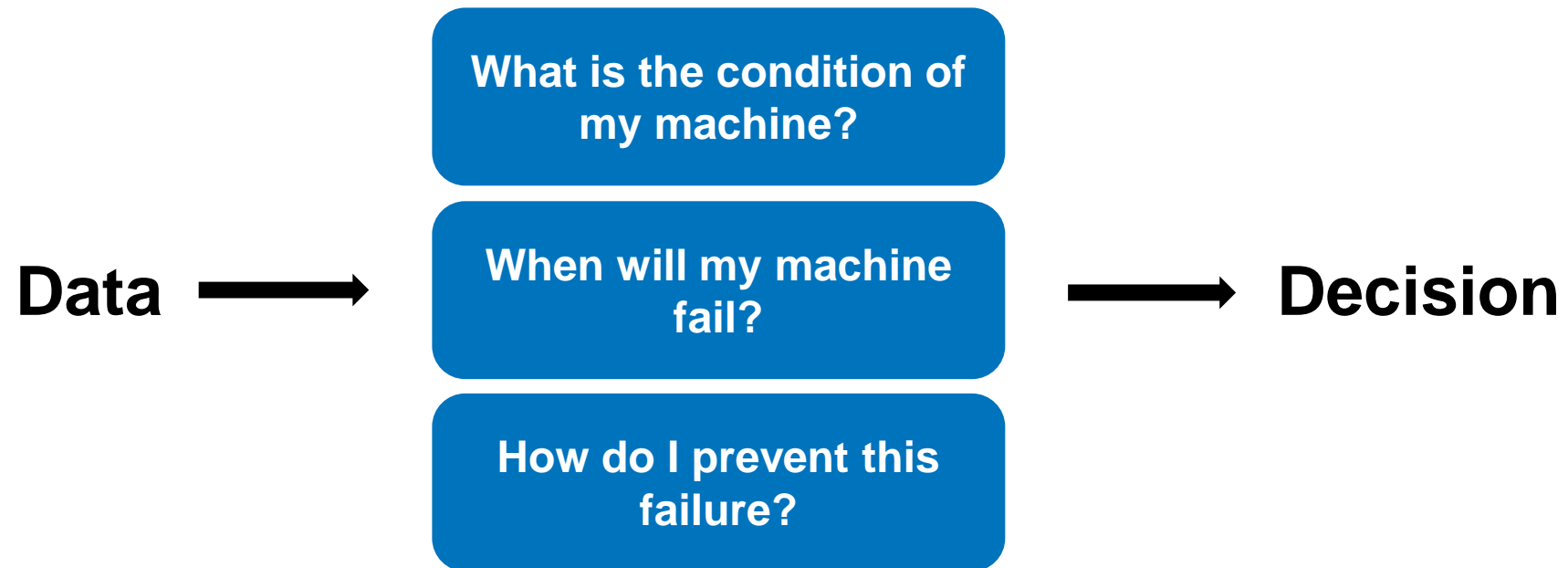
**Software Innovations** @BoschSI · Jan 31  
 How to develop a #DataAnalytics tool for #PredictiveMaintenance in 1 week? [youtube.com/watch?v=9mas0b...](http://youtube.com/watch?v=9mas0b...) #IIoT #Industry40



**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](http://youtube.com)

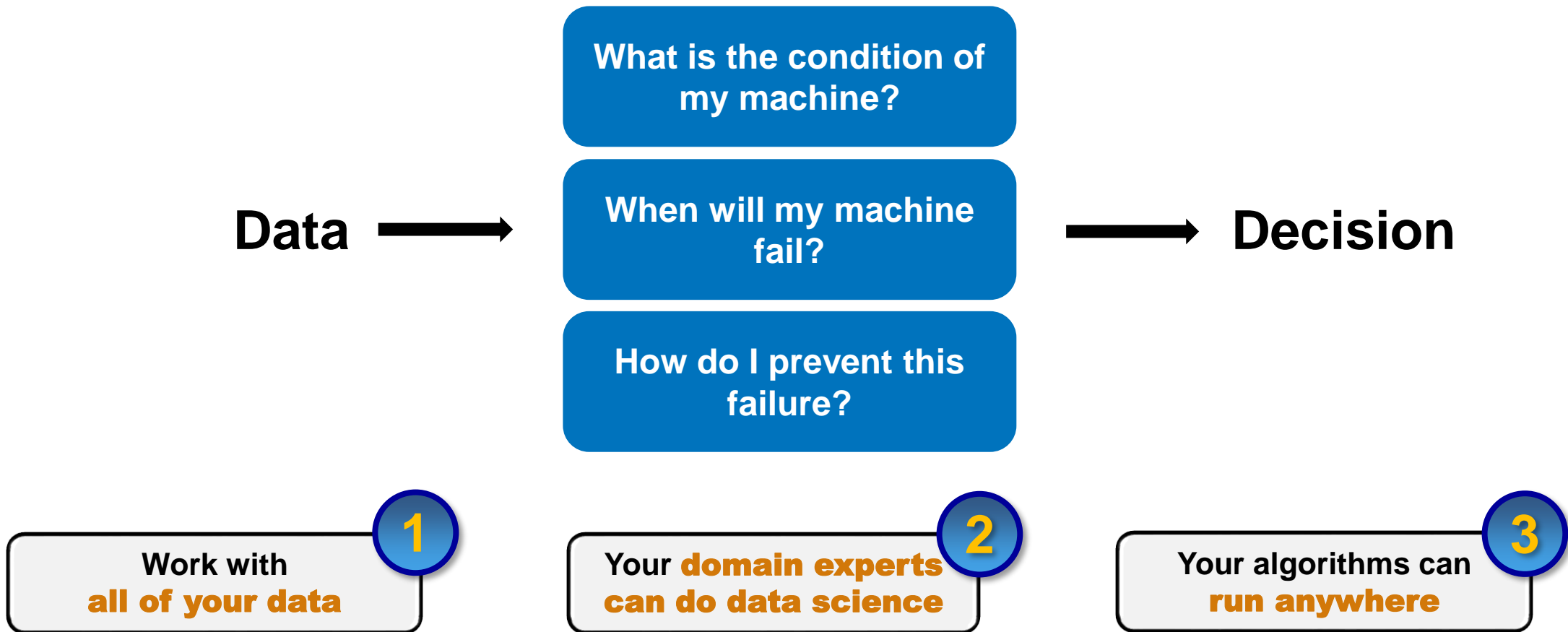
# What should a Predictive Maintenance Algorithm do?

*Turn large volumes of complex data into decisions*



# MATLAB Helps Build Predictive Maintenance Algorithms

*Turn large volumes of complex data into decisions*



# Baker Hughes Develops Predictive Maintenance Software for Gas and Oil Extraction Equipment

## Challenge

Develop a predictive maintenance system to reduce pump equipment costs and downtime

## Solution

Use MATLAB to analyze nearly one terabyte of data and create a neural network that can predict machine failures before they occur

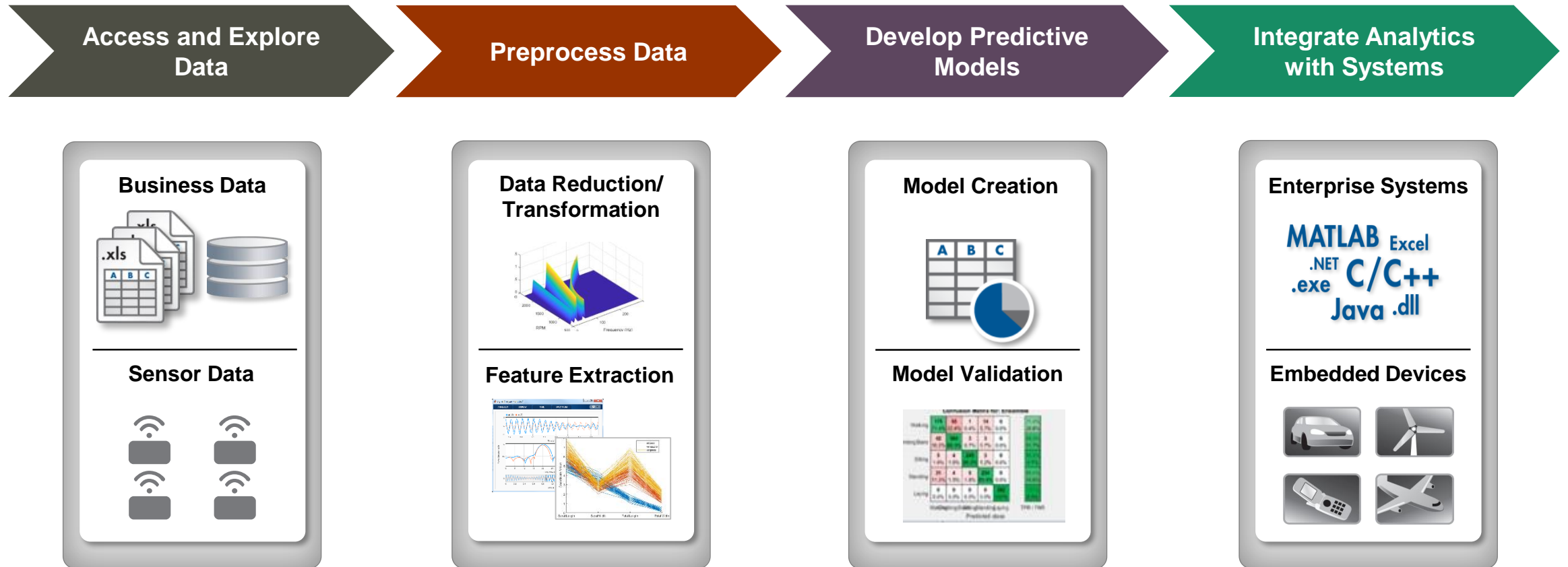
## Results

- **Savings of more than \$10 million projected**
- **Development time reduced tenfold**
- **Multiple types of data easily accessed**



Truck with positive displacement pump.

# 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

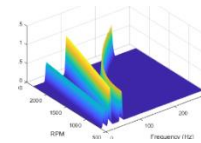


## Challenges

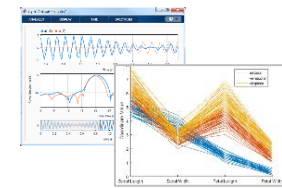
- I don't have enough data
- I have no data
- I have too much data to handle easily
- I have too many data sources
- My data is too messy

## Preprocess Data

### Data Reduction/ Transformation



### Feature Extraction



# Access and Preprocess Data

Access and Explore Data

## Challenges

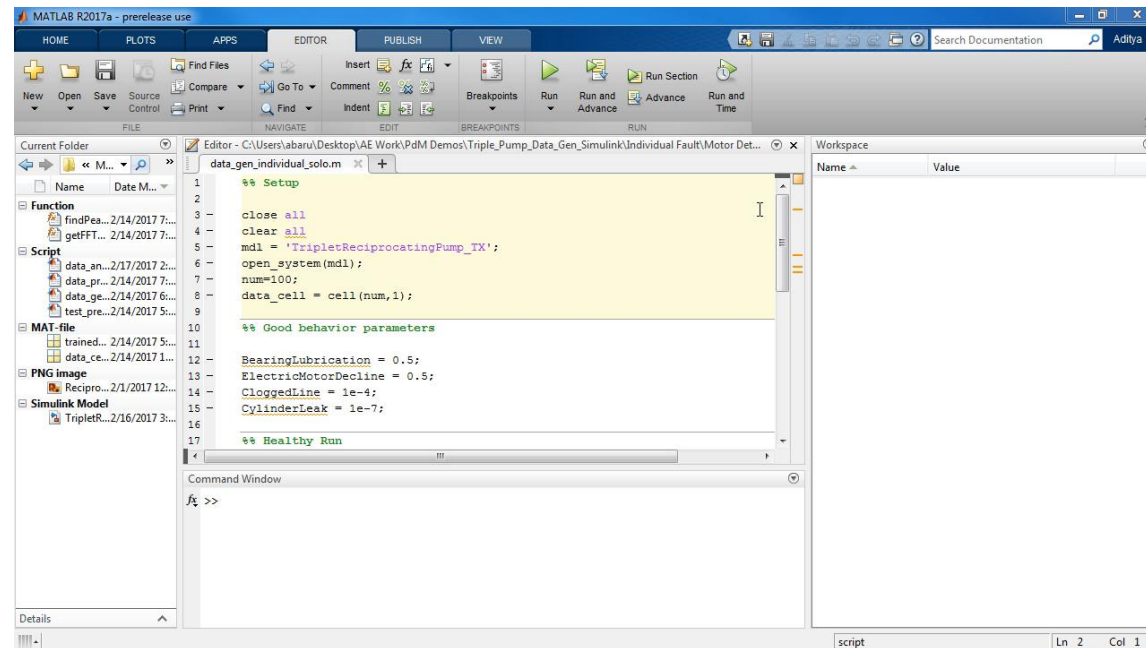
- I don't have enough data
- I have no data

Preprocess Data

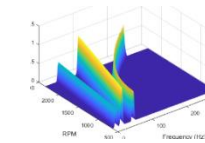
### Business Data



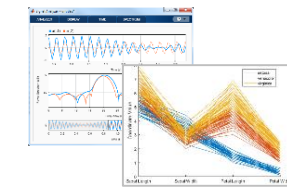
### Sensor Data



### Data Reduction/ Transformation



### Feature Extraction



# Access and Preprocess Data

Access and Explore Data

## Challenges

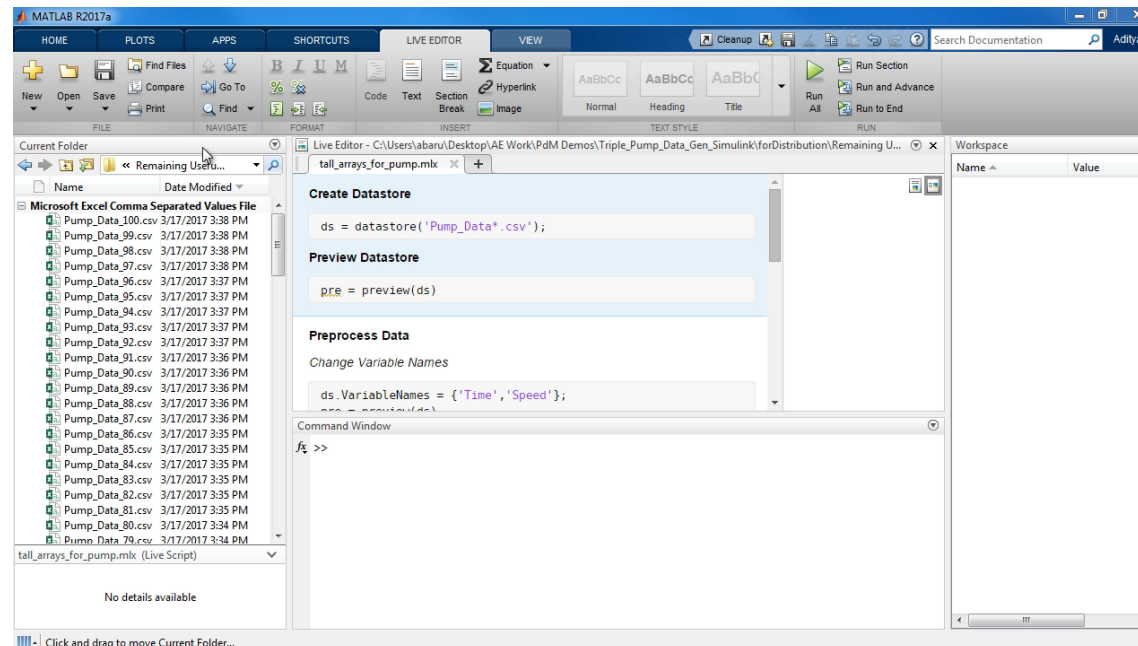
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Preprocess Data

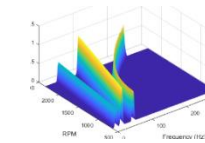
### Business Data



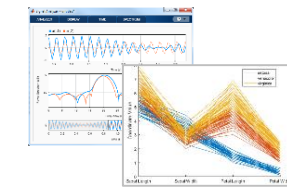
### Sensor Data



### 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**

## Access and Preprocess Data

- Baker Hughes Develops Predictive Maintenance Software for Gas and Oil Extraction Equipment

***“MATLAB gave us the ability to convert previously unreadable data into a usable format; automate filtering, spectral analysis, and transform steps for multiple trucks and regions; and ultimately, apply machine learning techniques in real time to predict the ideal time to perform maintenance.”***

– Gulshan Singh, Baker Hughes



# Build Predictive Models



**Business Data**

---

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**Data Reduction/  
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**Feature Extraction**

2

**Model Creation**

---

**Model Validation**

**Enterprise Systems**

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

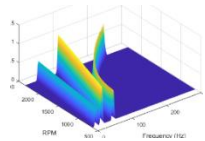
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**Embedded Devices**

# Build Predictive Models

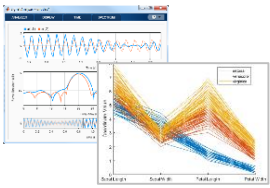
## Preprocess Data

**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


## Develop Predictive Models

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

Command Window  
fx >>

**Model Creation**

---

**Model Validation**

	Healthy	Warning	Alert	Failure	Model
Healthy	95%	0%	0%	0%	95%
Warning	10%	80%	0%	0%	90%
Alert	0%	0%	90%	0%	90%
Failure	0%	0%	0%	100%	100%
Model	95%	80%	90%	100%	93%

# Build Predictive Models

2

Your domain experts can do data science

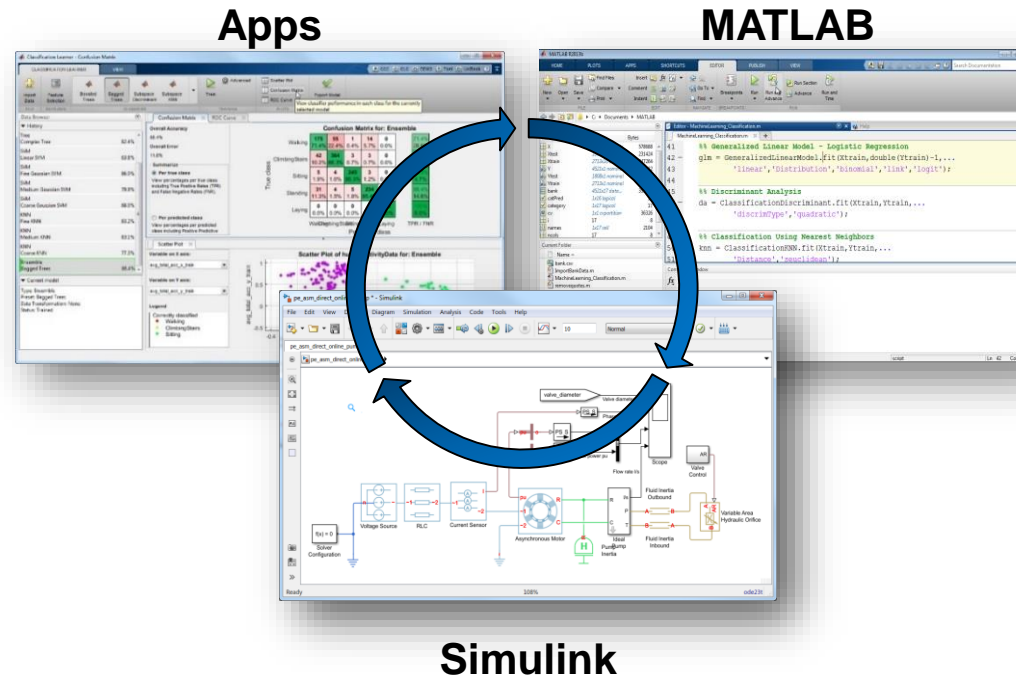
Preprocess Data

Develop Predictive Models

**Data Reduction/Transformation**

---

**Feature Extraction**



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

**Model Creation**

---

**Model Validation**

# Build Predictive Models

***“As a manufacturing company we don’t have data scientists with machine learning expertise, but MathWorks provided the tools and technical knowhow that **enabled us to develop a production preventative maintenance system in a matter of months,**”***

– Dr. Michael Kohlert, MONDI

***“...[We] enable engineers to quickly and easily layout algorithms without special knowledge in computer science...”***

– Jérôme Lacaille, Safran



The image displays the SAFRAN Snecma logo, with a blue stylized 'S' followed by the word 'SAFRAN' in bold and 'Snecma' in a smaller font below it. To the right of the logo is a detailed view of a jet engine, showing the fan blades, compressor, and turbine sections.



# Deploy and Integrate



**Business Data**

---

**Sensor Data**

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**Data Reduction/  
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2

**Model Creation**

---

**Model Validation**

3

**Enterprise Systems**

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

### 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

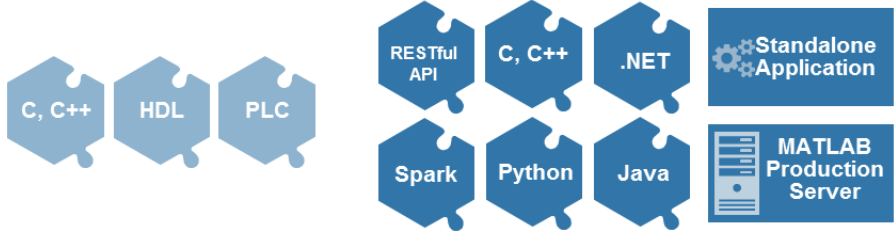
Model Creation

---

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

# Deploy and Integrate

*“The protection algorithms for our conventional HVDC system took about six months to develop and test in C. **I re-implemented the same algorithms in Simulink and Stateflow and had them working in a single week.**”*

*– Anthony Totterdell, Alstom Grid*

*“**Using MATLAB and MATLAB Compiler, I can develop an application at least 100 times faster than I could with Visual Basic or C.** The time we saved on the very first application that we wrote in MATLAB more than paid for the software.”*

*– Roger Schultz, Halliburton Energy Services*





# Summary: MATLAB Helps Build Predictive Maintenance Algorithms



**Business Data**

---

**Sensor Data**

**1**

**Data Reduction/  
Transformation**

---

**Feature Extraction**

**2**

**Model Creation**

---

**Model Validation**

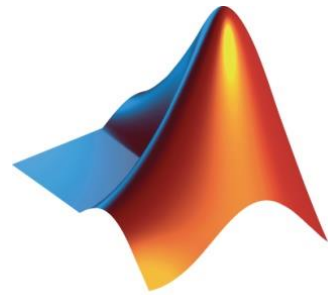
**3**

**Enterprise Systems**

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

---

**Embedded Devices**



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