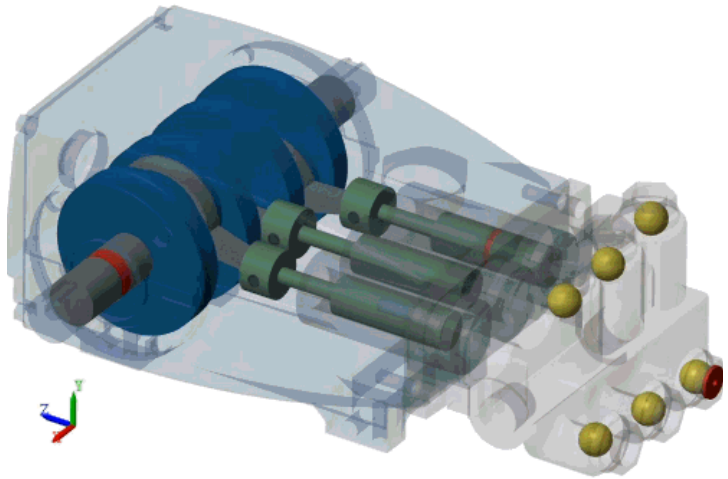
MATLAB EXPO 2018

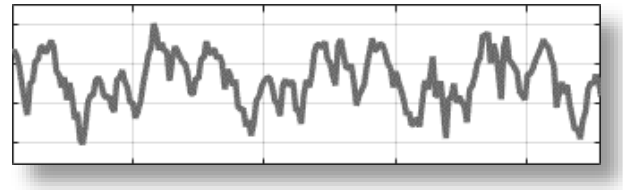
Predictive Maintenance

From Development to IoT Deployment

Mehernaz Savai

What is Predictive Maintenance?





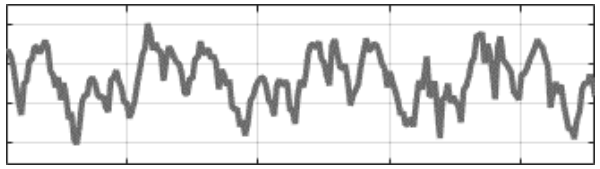
Translate

Turn off instant translation

English | Spanish | French | Pump - detected

English | Russian | Greek

Translate



1/5000

I need help.

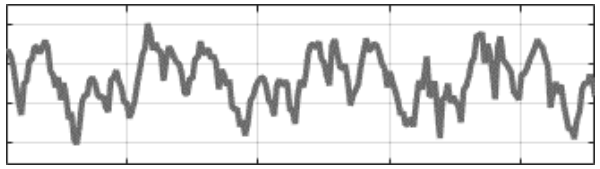
Translate

Turn off instant translation

English | Spanish | French | Pump - detected

English | Russian | Greek

Translate

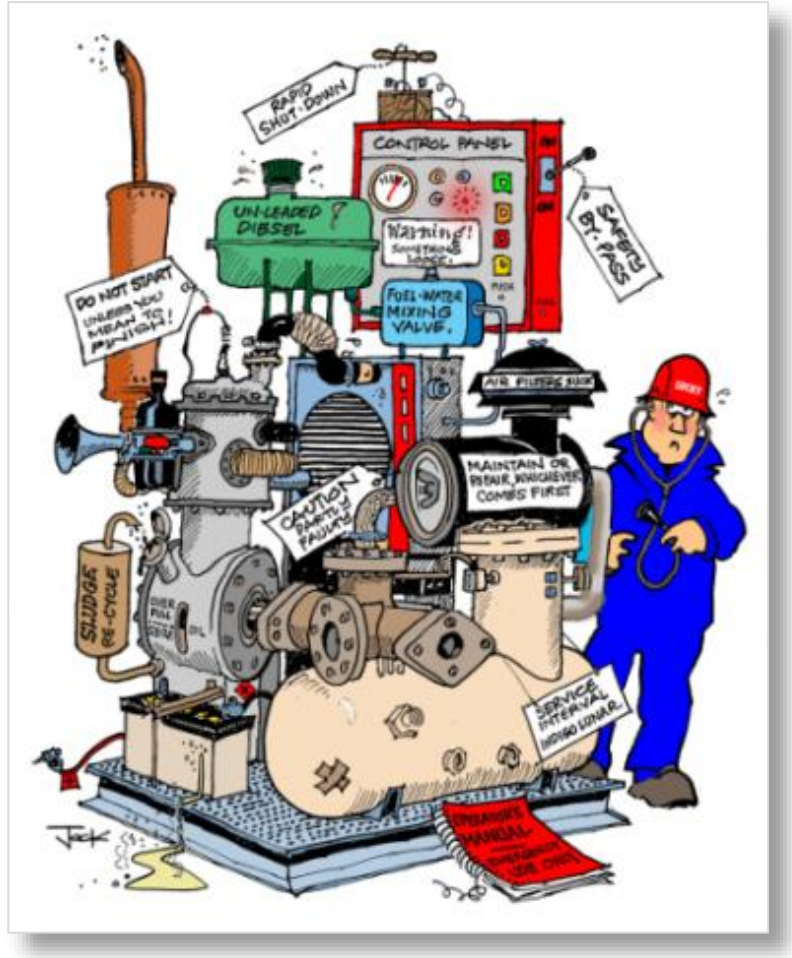


1/5000

I need help. One of my cylinders is blocked. I will shut down your line in 15 hours

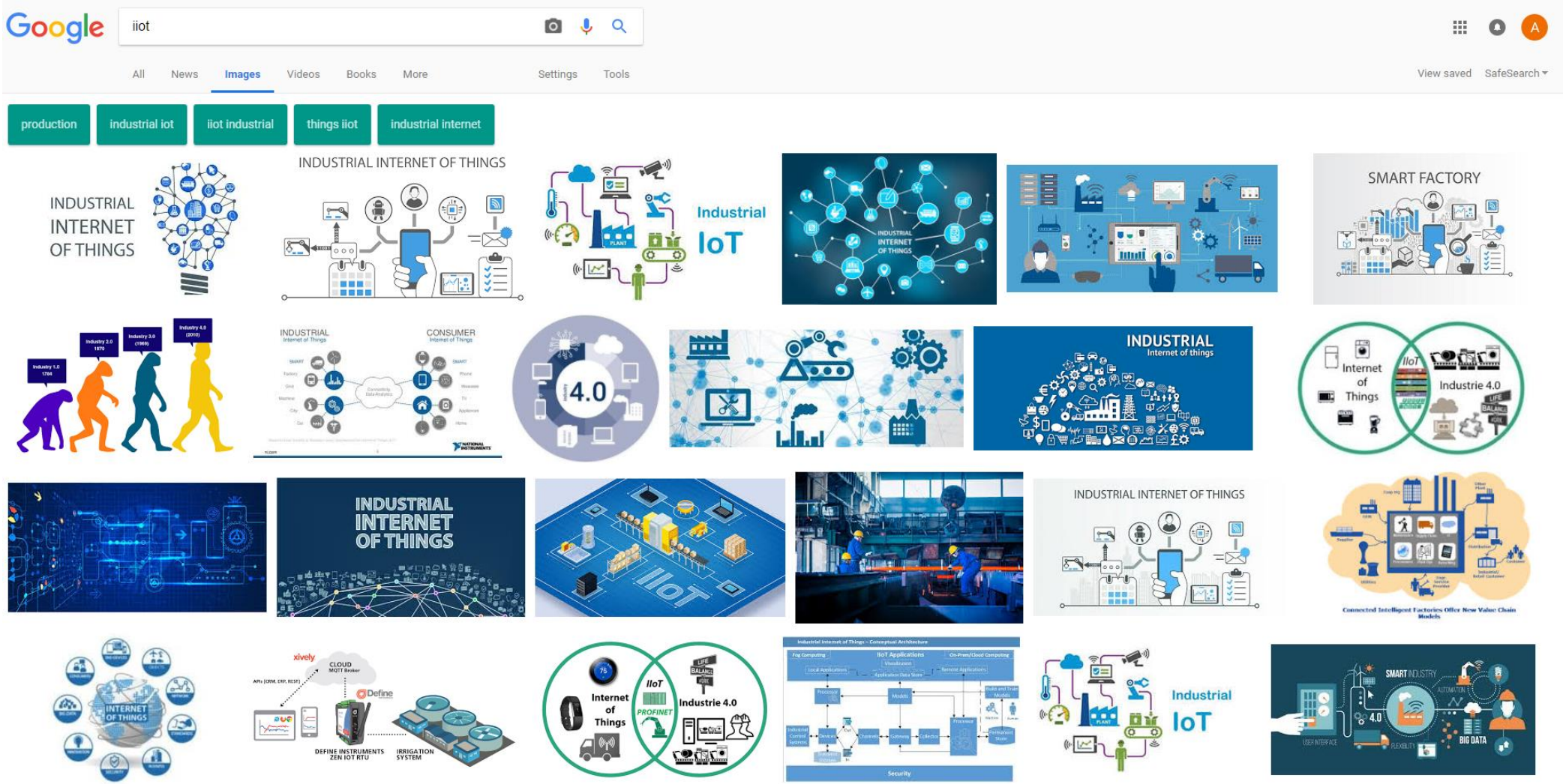
What do you expect from predictive maintenance?

- Maintenance cares about day-to-day operations
  - Reduced downtime
- Operations & IT look at the bigger picture
  - Improved operating efficiency
- Engineering groups get product feedback
  - Better customer experience
- Upper management wants to drive growth
  - New revenue streams

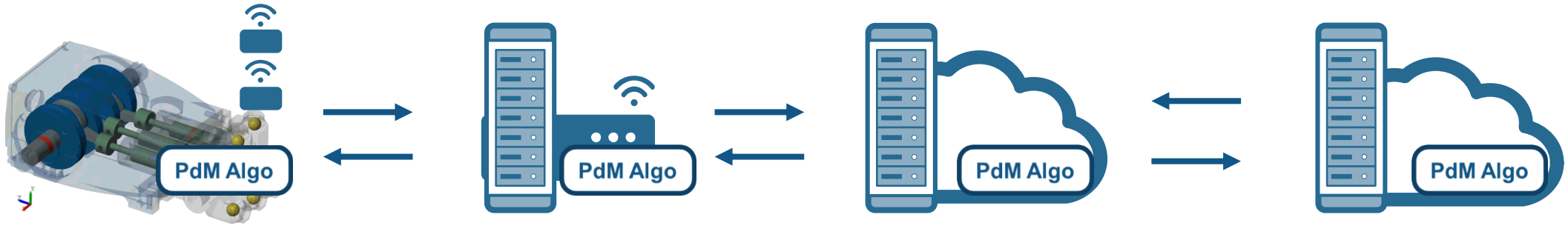


Source: Tensor Systems

Industrial Internet of Things



Industrial Internet of Things

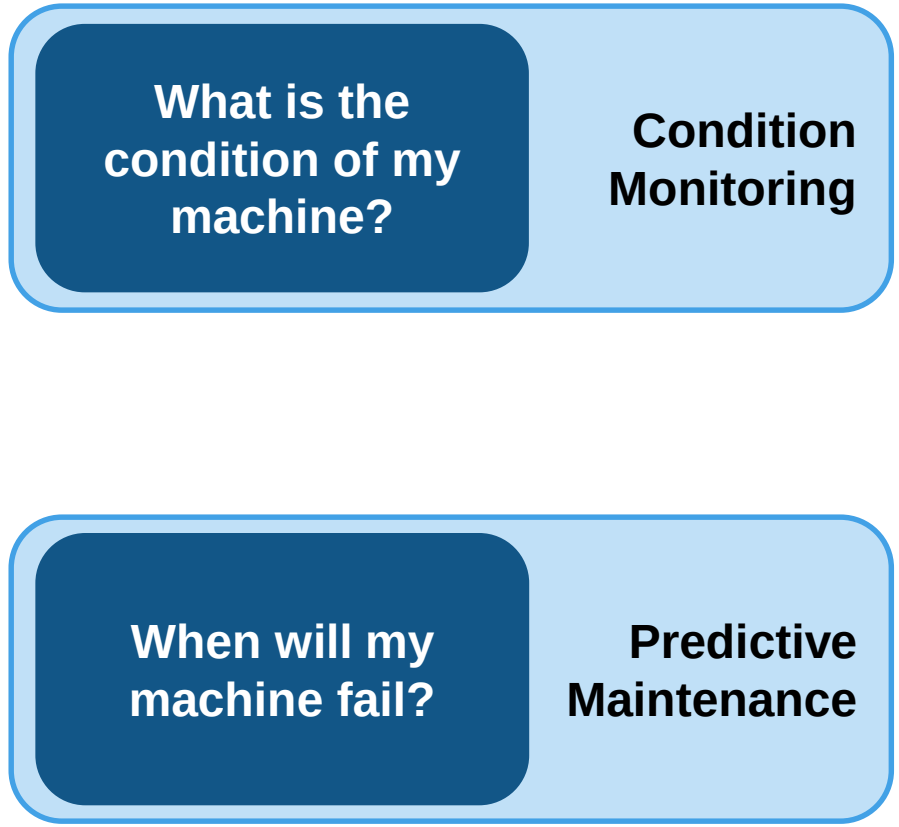


Agenda

- Where do you start?
- What if you don’t have the data you need?
- How do you reduce data transmission and storage costs?
- How do you deliver your analytics to different users?

Challenges: Where do you start?

- How can I easily perform feature extraction?
- What algorithms do I have access to?
- Where can I find examples I can use?



Solution: Predictive Maintenance Algorithms

Condition Indicators

Remaining Useful Life

- Signal based fea
- Model based fea
- Feature selectio

-to-failure history

wn failure threshold

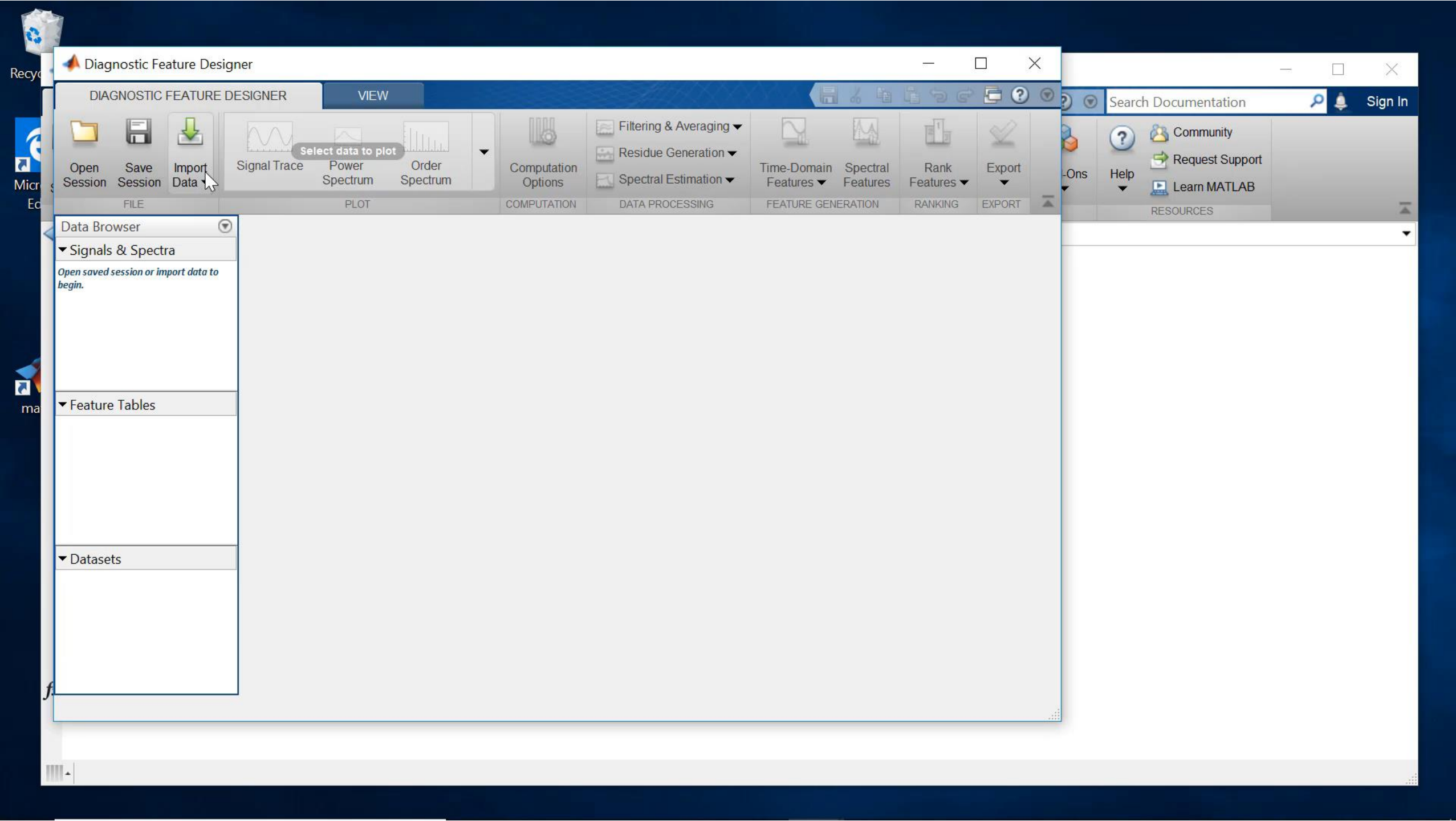
time data with or out covariates

Learn More:

Predictive Maintenance Toolbox
New!

Booth:
Machine Learning/
Deep Learning

Reference examples for motors, gearboxes, batteries, and other machines


Diagnostic Feature Designer
DIAGNOSTIC FEATURE DESIGNER
VIEW
Open Session
Save Session
Import Data
Select data to plot
Signal Trace
Power Spectrum
Order Spectrum
Computation Options
Filtering & Averaging
Residue Generation
Spectral Estimation
Time-Domain Features
Spectral Features
Rank Features
Export
FILE
PLOT
COMPUTATION
DATA PROCESSING
FEATURE GENERATION
RANKING
EXPORT
Data Browser
Signals & Spectra
Open saved session or import data to begin.
Feature Tables
Datasets
Search Documentation
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Community
Request Support
Learn MATLAB
Help
RESOURCES

Agenda

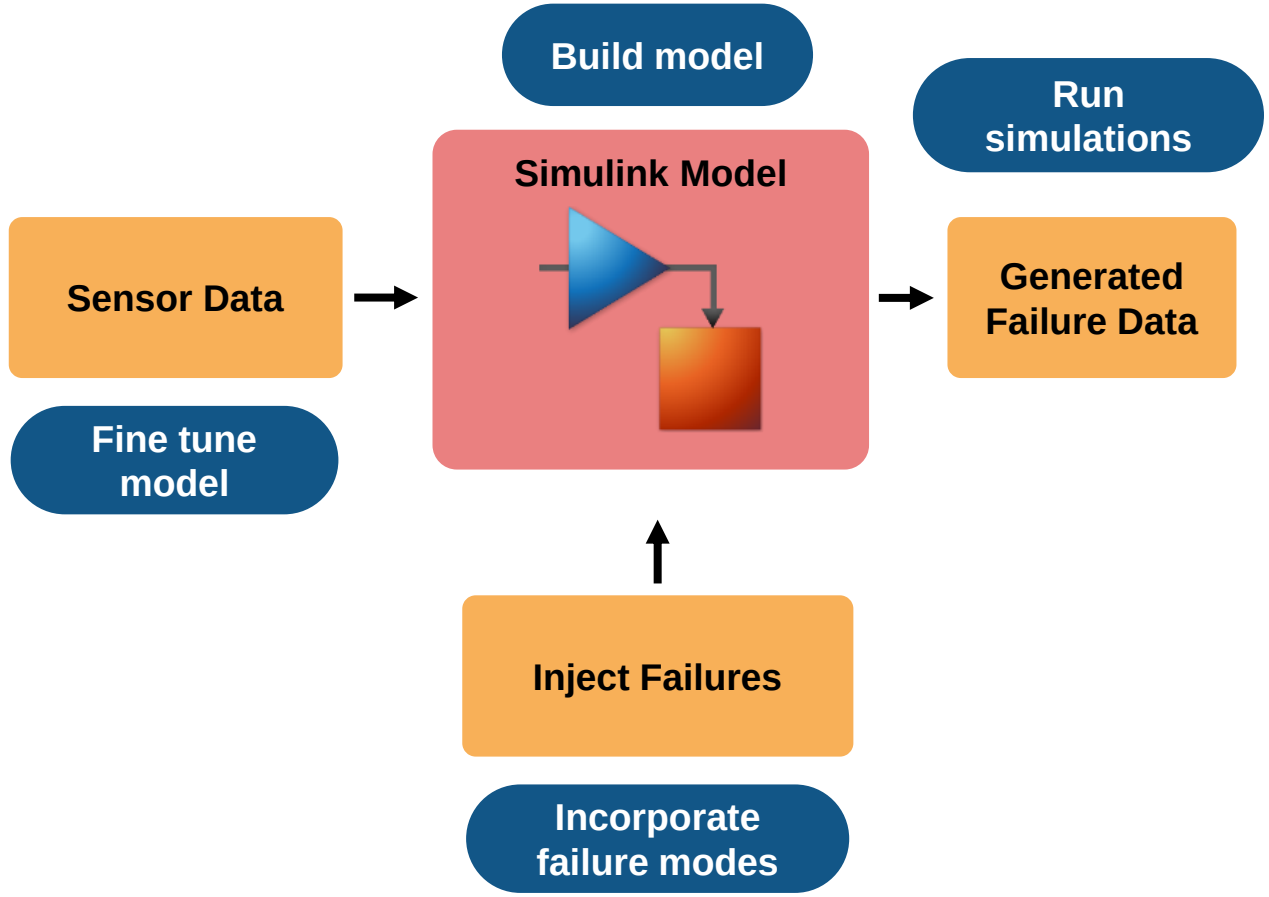
- Where do you start?
- What if you don’t have the data you need?
- How do you reduce data transmission and storage costs?
- How do you deliver your analytics to different users?

Challenges: What if you don’t have the data you need?

- Lack of labelled failure data
- Multiple failure modes and failure combinations possible
- Different machines can show different behavior for the same failure

Solution: Generating failure data from Simulink models

- How do I model failure modes?
  - Work with domain experts and the data available
  - Vary model parameters or components
- How do I customize a generic model to a specific machine?
  - Fine tune models based on real data
  - Validate performance of tuned model



MATLAB R2018a

HOME | PLOTS | APPS | MECHANICS EXPLORERS | VIEW

CleanUp | Search Documentation | Log In

File Explorer Simulation View Tools Help

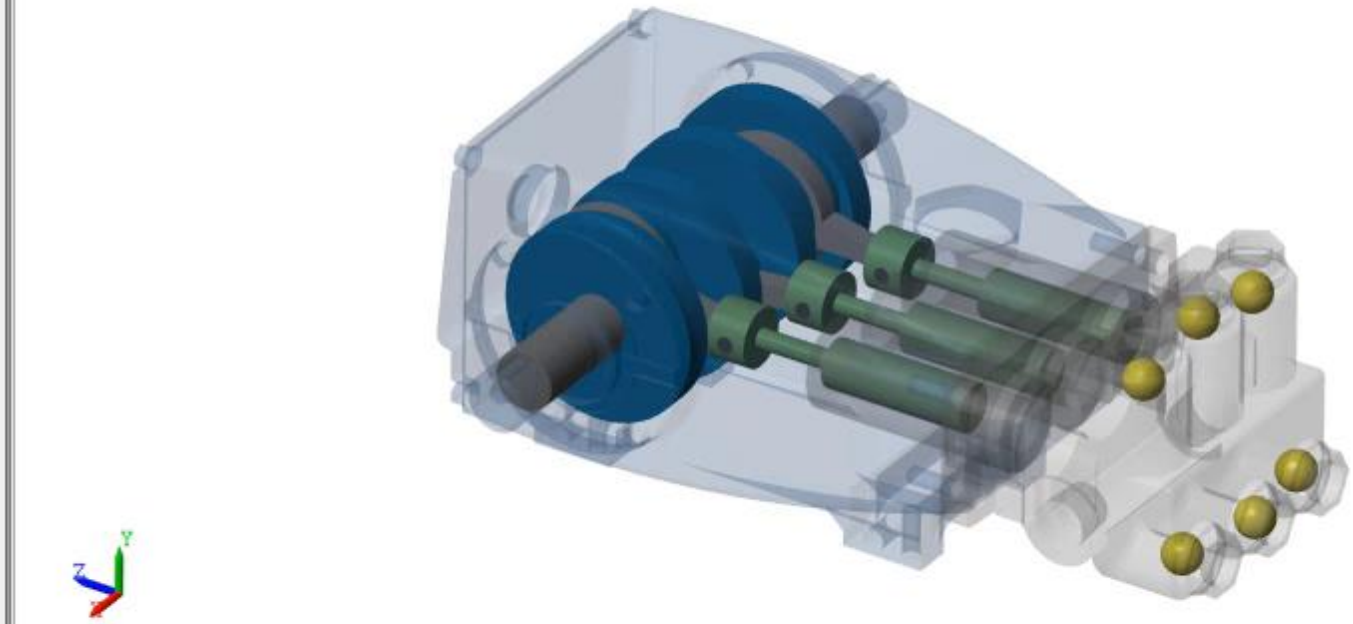
View convention: Z up (XY Top)

MENU AND TOOLBARS

Mechanics Explorers - Mechanics Explorer-sm_pump_triplex

Mechanics Explorer-sm_pump_triplex

sm_pump_triplex
- Driver
- Pump
- Connection Frames



T = [0,1.5]

1/8X

Time 1.5

Command Window

fx >>

Find out more:

2 PM Session: Developing Battery Management System Using Simulink

2:30 PM Session: Mechatronic Design for Aircraft Systems

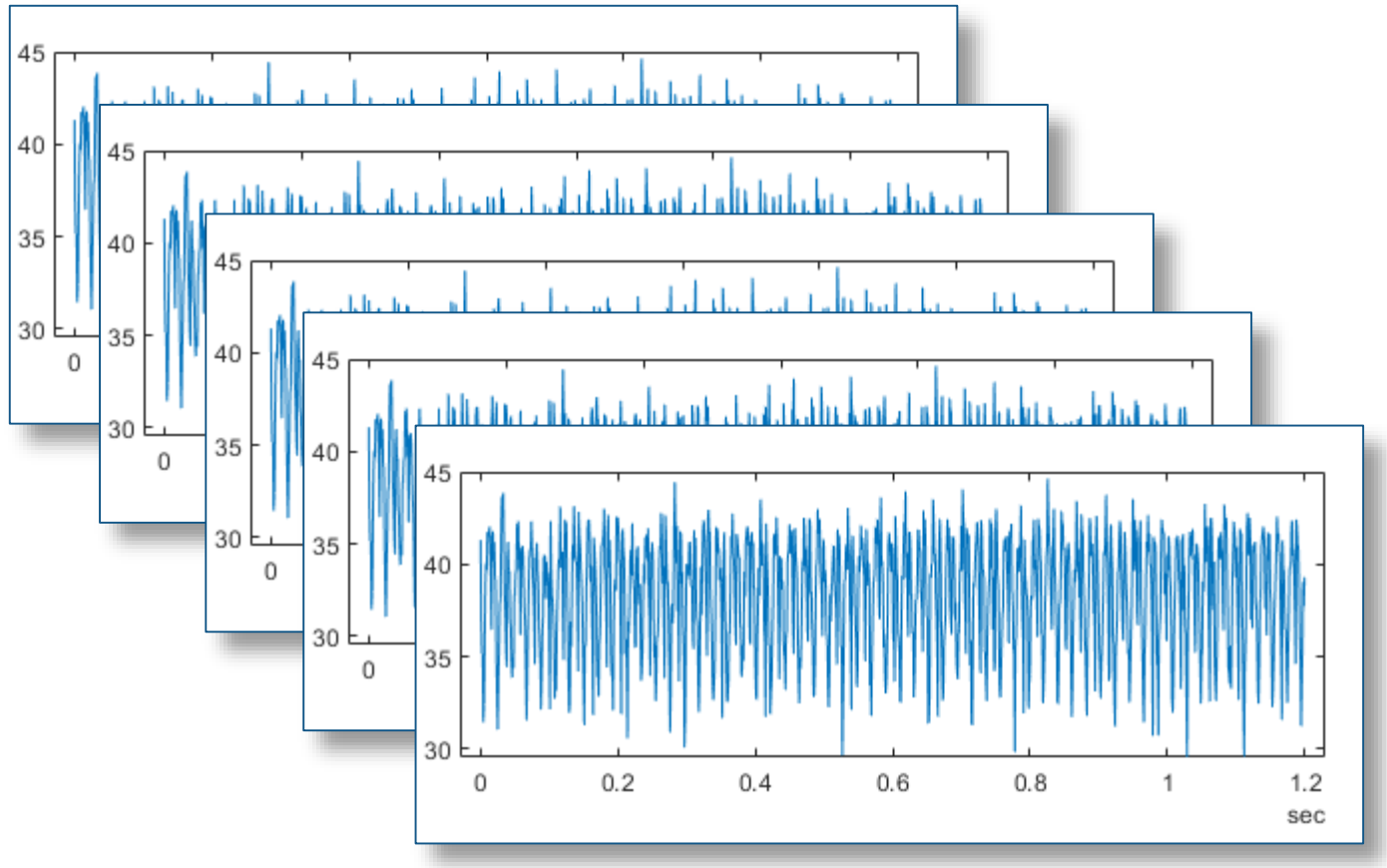
Agenda

- Where do you start?
- What if you don’t have the data you need?
- How do you reduce data transmission and storage costs?
- How do you deliver your analytics to different users?

Challenges: How do you reduce data transmission/storage costs?

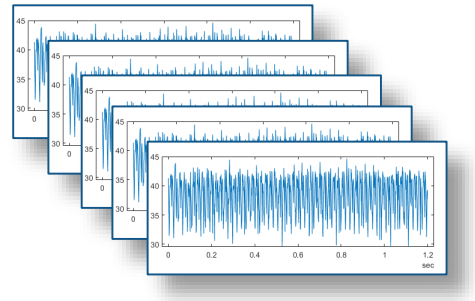
- 1 day ~ 1.3 GB
- 20 sensors/pump ~26 GB/day
- 3 pumps ~ 78 GB/day
- Satellite transmission
  - Speeds approx. 128-150 kbps,
  - Cost $1,000/ 10GB of data
- Needle in a haystack problem

Pump flow sensor *1 sec ~ 1000 samples ~16kB*



Solution: Feature extraction at the Edge

- How do you extract features?
  - Signal processing methods
  - Statistics & model-based methods
- Which features should you extract?
  - Depends on the data available
  - Depends on the hardware available
- How do I deal with streaming data?
  - Determine buffer size
  - Extract features over a moving buffer window



Edge Devices

qMean	qVar	qSkewness	qKurtosis
38.4945	9.2306	-0.5728	2.4662
qPeak2P...	qCrest	qRMS	qMAD
15.2351	1.1553	38.6141	2.5562

MATLAB R2018a

HOME | PLOTS | APPS | LIVE EDITOR | INSERT | VIEW

New | Open | Save | Find Files | Compare | Print | Go To | Find | Text | Normal | Code | Section Break | Run Section | Run and Advance | Run to End | Run | Step | Stop

FILE | NAVIGATE | TEXT | CODE | SECTION | RUN

C: ▸ Users ▸ abaru ▸ Desktop ▸ Expo 2018 ▸ FinalDemo ▸ Demo_Files ▸ Data_Reduction ▸

Current Folder

Name

- Data
  - pdmRecipPump_log_1.mat
  - pdmRecipPump_log_2.mat
  - pdmRecipPump_log_3.mat
  - pdmRecipPump_log_4.mat
  - pdmRecipPump_log_5.mat
  - pdmRecipPump_log_6.mat
  - pdmRecipPump_log_7.mat
  - pdmRecipPump_log_8.mat
  - pdmRecipPump_log_9.mat
  - pdmRecipPump_log_10.mat
  - pdmRecipPump_log_11.mat
  - pdmRecipPump_log_12.mat
  - pdmRecipPump_log_13.mat
  - pdmRecipPump_log_14.mat
  - pdmRecipPump_log_15.mat
  - pdmRecipPump_log_16.mat
  - pdmRecipPump_log_17.mat
  - pdmRecipPump_log_18.mat
  - pdmRecipPump_log_19.mat
  - pdmRecipPump_log_20.mat
  - pdmRecipPump_log_21.mat
  - pdmRecipPump_log_22.mat
  - pdmRecipPump_log_23.mat

pdmRecipPump_log_13.mat (MAT-file)

Live Editor - C:\Users\abaru\Desktop\Expo 2018\FinalDemo\Demo_Files\Data_Reduction\Expo_Data_Preprocessing_CodeGen.mlx

Expo_Data_Preprocessing_CodeGen.mlx | featureExtractionBuffer.m

Algorithm Development for Feature Extraction at the Edge

Processing and Extracting Features from the Simulation Results

The model is configured to log the pump output pressure, output flow, motor speed and motor current.

```
ens = simulationEnsembleDatastore('.\Data');
ens.SelectedVariables = ["qOut_meas", "SimulationInput"];
reset(ens)
data = read(ens);
[flow,time_unit] = preprocess(data);
figure;
plot(flow.Time,flow.Data);
```

```
% Decide which features to extract

ens.DataVariables = [ens.DataVariables; ...
    "qMean"; "qVar"; "qSkewness"; "qKurtosis"; ...
    "qPeak2Peak"; "qCrest"; "qRMS"; "qMAD"; "qCSRange"];
ens.ConditionVariables = ["Time_Unit"];

feat = extractCI(flow);
dataToWrite = [time_unit, feat];
writeToLastMemberRead(ens,dataToWrite{:})
```

Agenda

- Where do you start?
- What if you don’t have the data you need?
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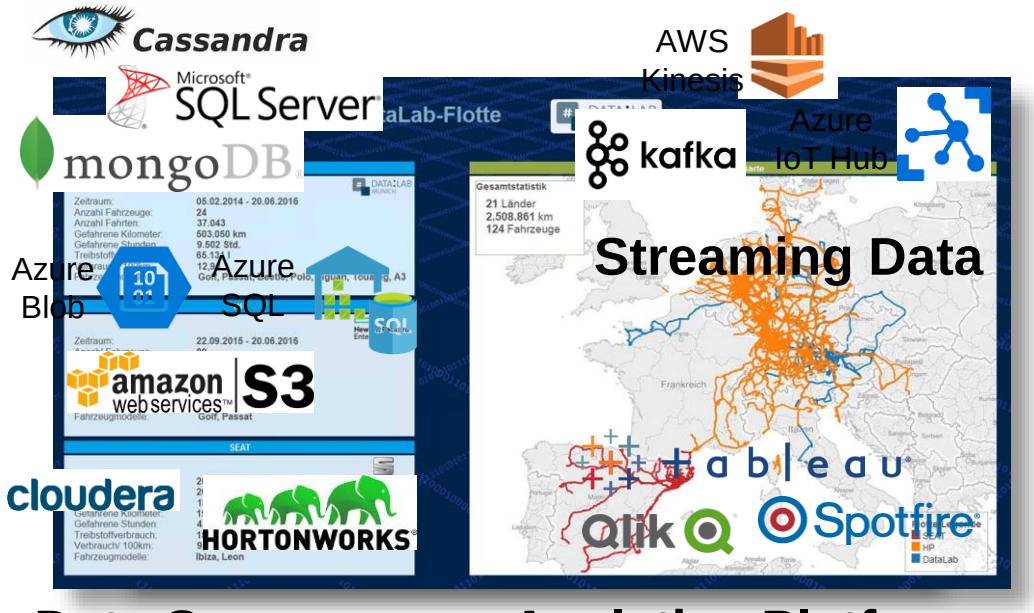
Challenges: What do your end users expect?

- Maintenance needs simple, quick information
  - Hand held devices, Alarms
- Operations needs a birds-eye view
  - Integration with IT & OT systems
- Customers expect easy to digest information
  - Automated reports



Solution: Flexible deployment of algorithms

- Can I reuse my algorithm code for deployment?
  - Code generation at the Edge
  - Libraries & executables for IT/OT systems
- How do I update my predictive model?
  - Retrain degradation models for RUL estimation
  - Retrain classification models for fault isolation
- How do I integrate with my IT/OT systems?
  - Connect to data sources & scale computations
  - Connect to dashboards & analytics platforms

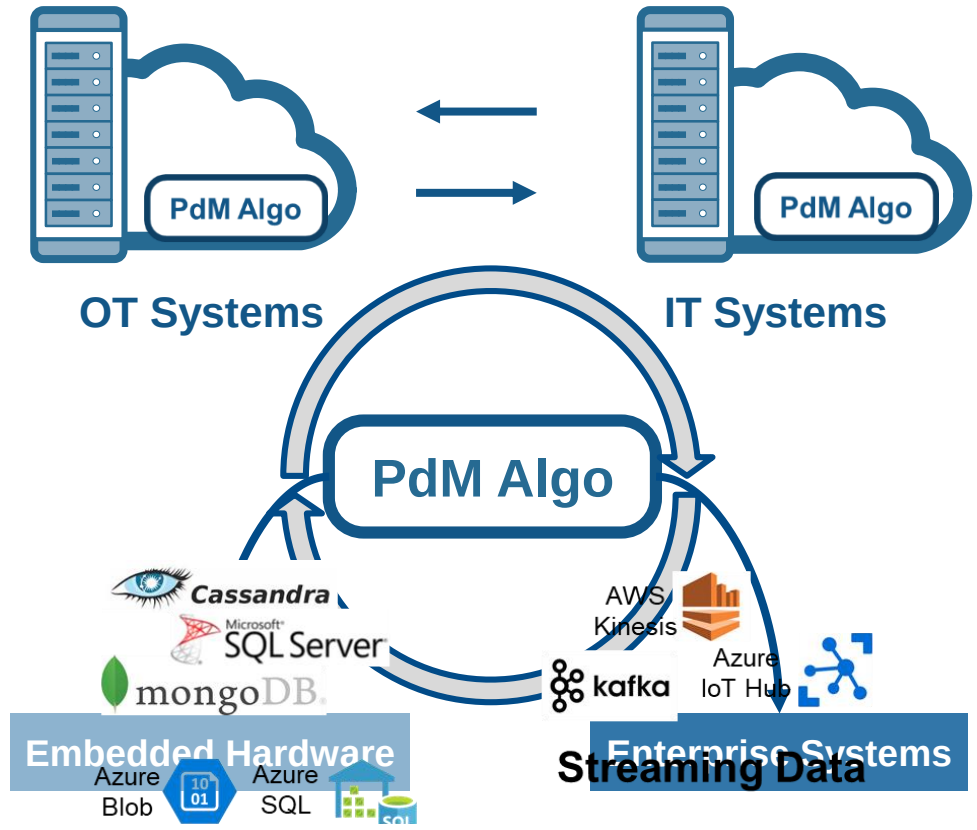
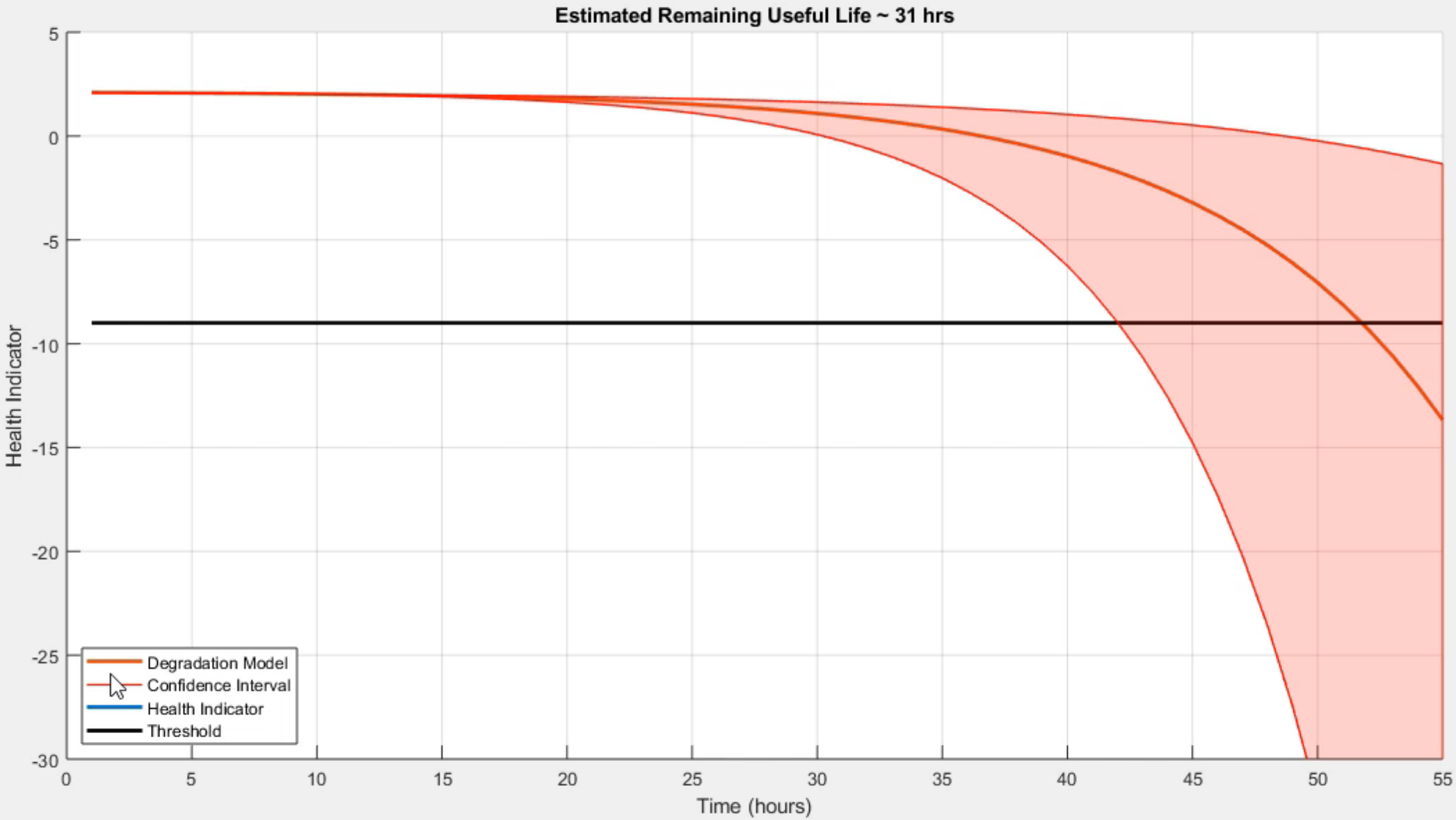


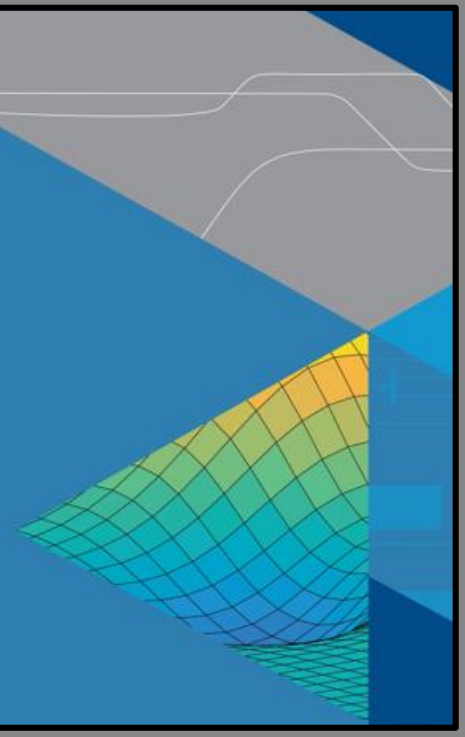
Figure 1

File Edit View Insert Tools Desktop Window Help



Find out more:

2 PM Session: Techniques for Deploying AI for Near-Real-Time Engineering Decisions



Mondi: Statistics-Based Health Monitoring and Predictive Maintenance for Manufacturing Processes

One of Mondi Gronau's plastic production machines, which deliver about 18 million tons of plastic and thin film products annually.

Challenge

Reduce waste and machine downtime in plastics manufacturing plants

Solution

Use MATLAB to develop and deploy monitoring and predictive maintenance software that uses machine learning algorithms to predict machine failures

Results

- More than 50,000 euros saved per year
- Prototype completed in six months
- Production software run 24/7

Link to user story

"MathWorks Consulting's support is among the best I've seen; the consultants are fast and exceptionally knowledgeable. We've already seen a positive return on investment from cost savings, and now we have more budget and time to complete more machine learning projects that will provide similar benefits."

Dr. Michael Kohlert

Mondi

Why MATLAB & Simulink for Predictive Maintenance

- Where do you start?
  - Quick start with the new Predictive Maintenance Toolbox
- What if you don’t have the data you need?
  - Generate failure data from Simulink models
- How do you reduce data transmission and storage costs?
  - Extract features at edge nodes
- How do you deliver your analytics to different users?
  - Deploy algorithms to embedded hardware and/or enterprise systems

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