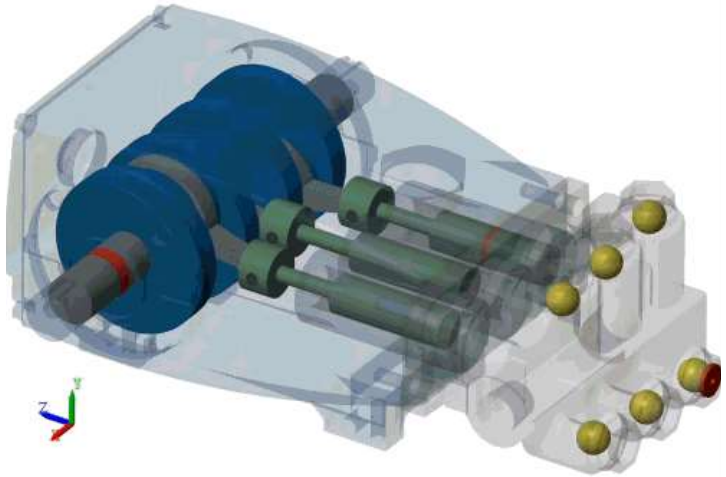
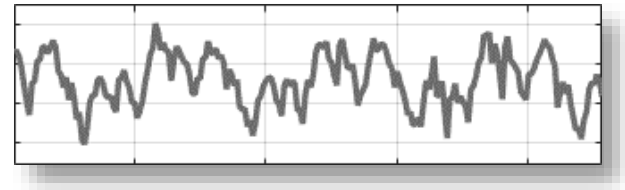
MATLAB EXPO 2019

건정성 관리 예측 모델 개발을 위한 MATLAB 활용 방안

엄준상

What is Predictive Maintenance?





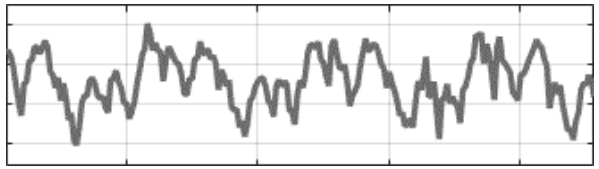
Translate

Turn off instant translation

English | Spanish | French | Pump - detected

English | Russian | Greek

Translate



1/5000

I need help.

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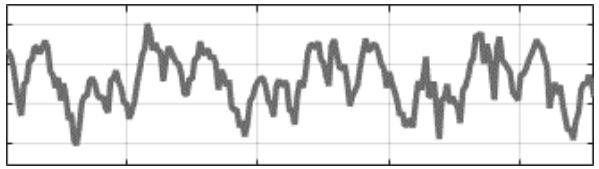

1/5000

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

A Predictive Maintenance Algorithm Answers These Questions

Is my machine operating normally?	Anomaly Detection
Why is my machine behaving abnormally?	Condition Monitoring
How much longer can I operate my machine ?	Remaining Useful Life Estimation

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Predictive Maintenance Toolbox for Developing Algorithms

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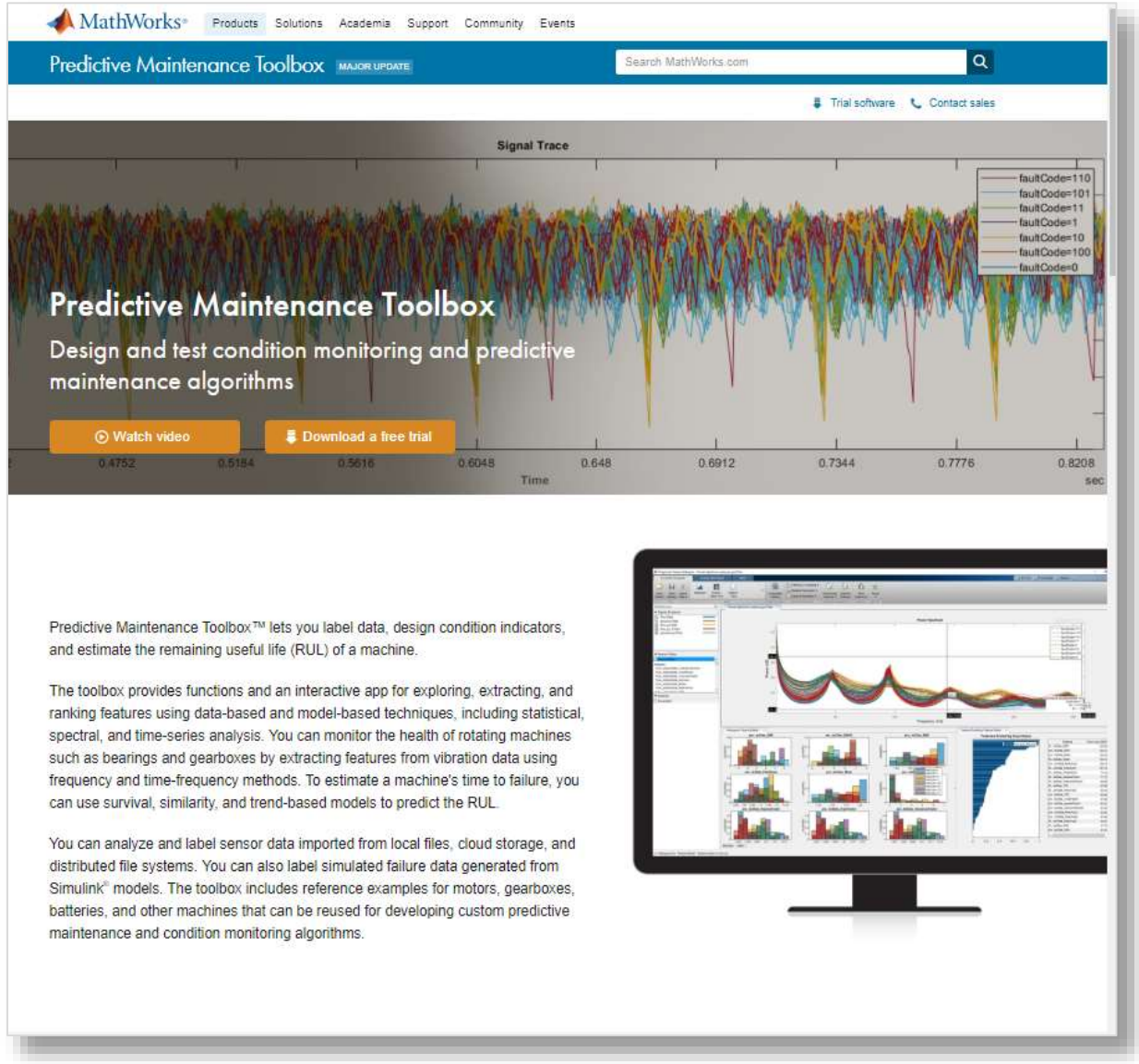
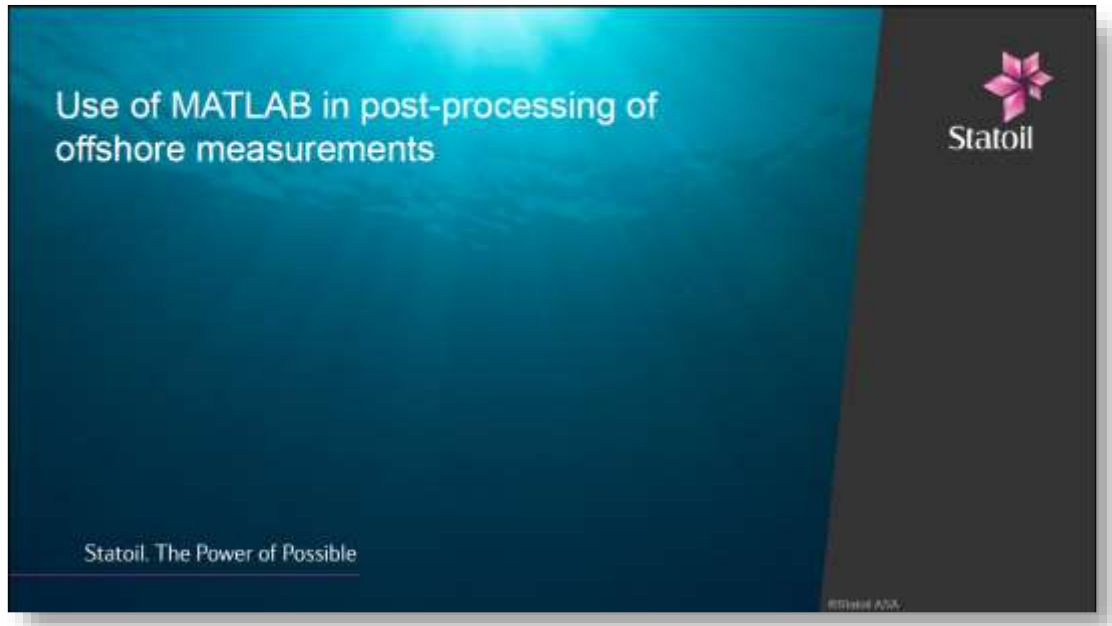


How are MathWorks Tools Used for Predictive Maintenance?

Link to user story



Link to user story

"…Subject Matter Expert Familiarity…"

"… [MATLAB is] Popular across the company…"

SAFRAN AEROSPACE · DEFENCE · SECURITY

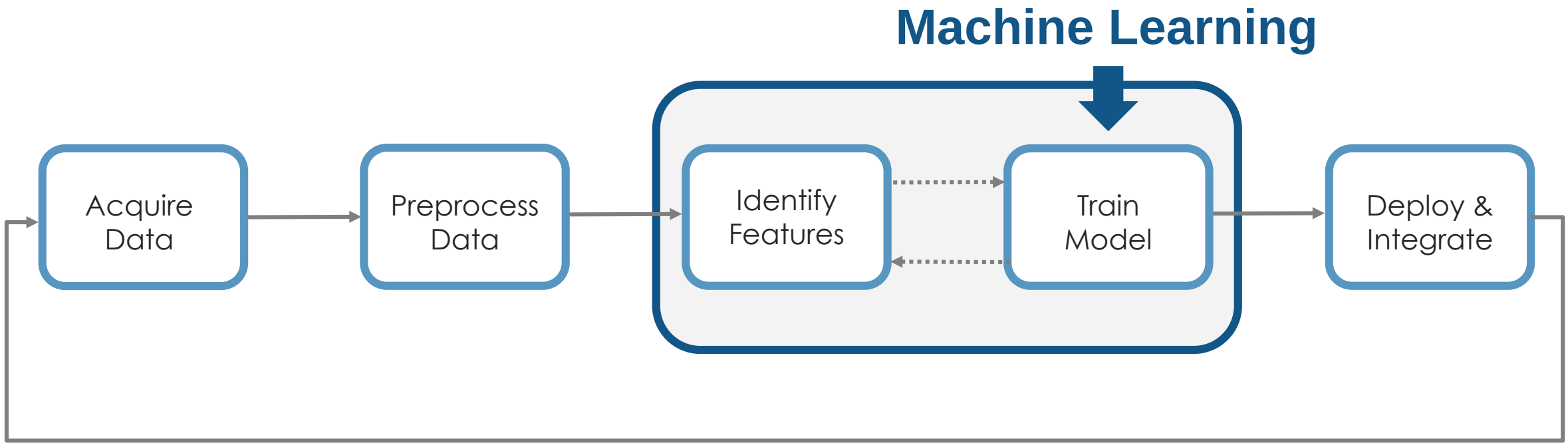
mondi

SNCF

Mercedes-Benz

BOSCH

Workflow for Developing a Predictive Maintenance Algorithm



Why MATLAB & Simulink for Predictive Maintenance

- Reduce the amount of data you need to store and transmit
- Explore approaches to feature extraction and predictive modeling
- Deliver the results of your analytics based on your audience
- Get started quickly…especially if you are an engineer

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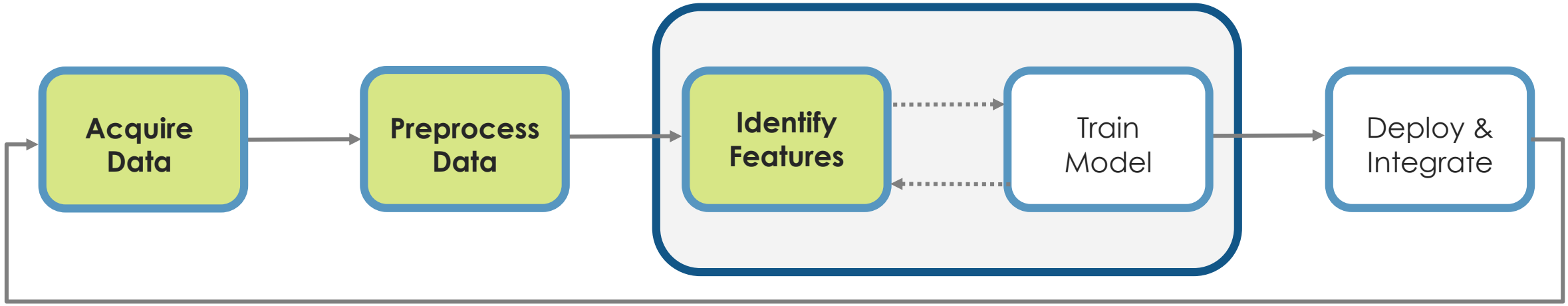
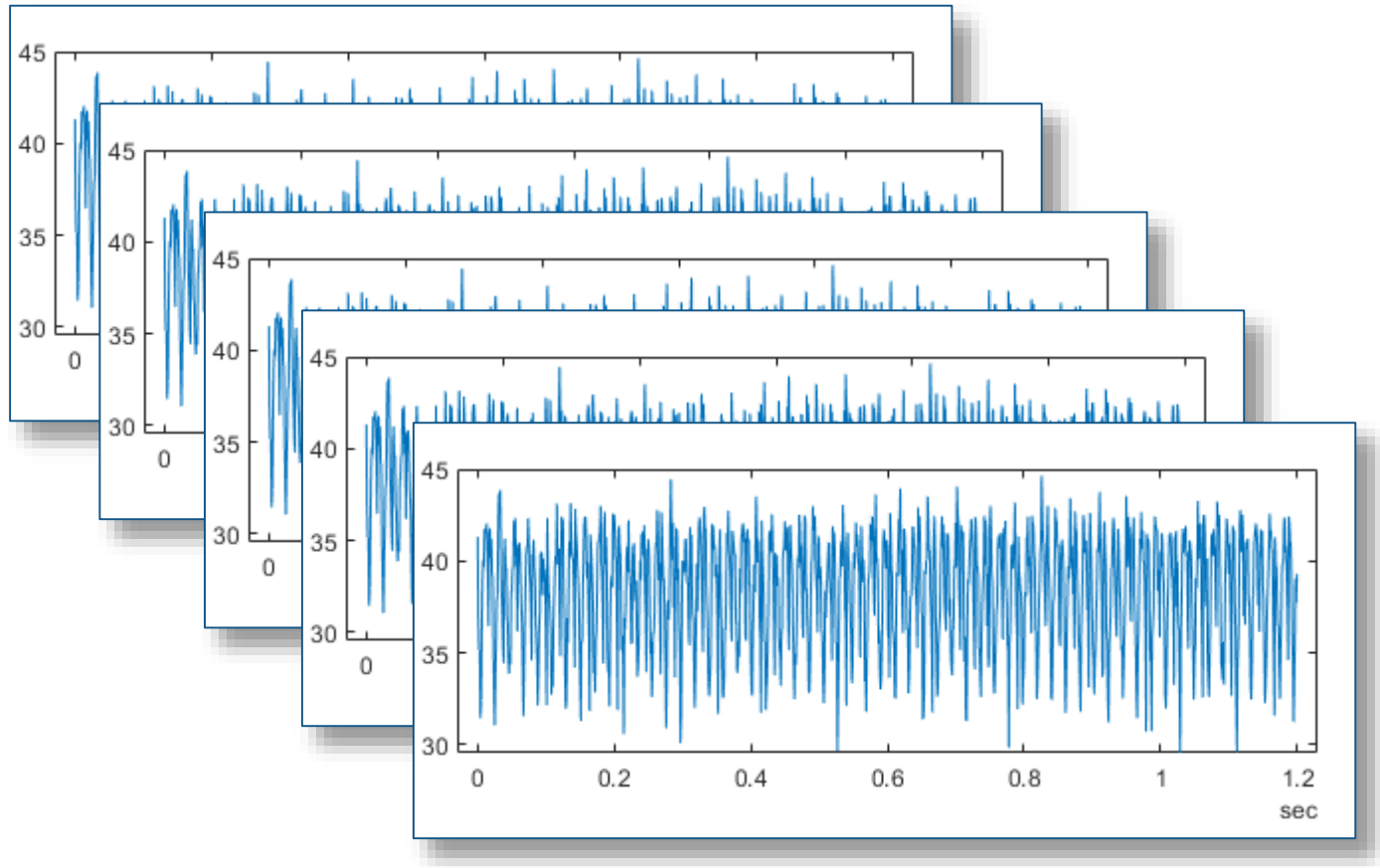


Challenges: How do you make sense of the ALL the data being collected?

- 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

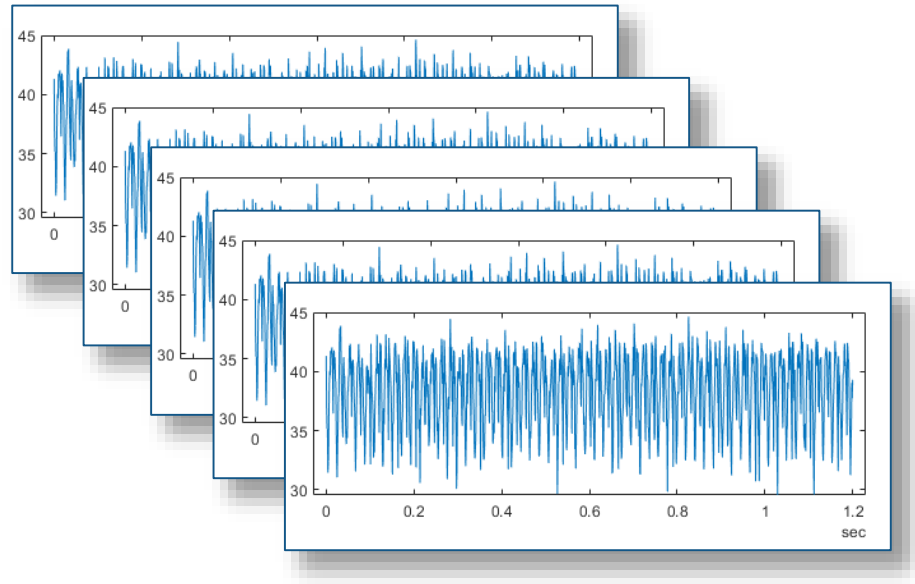
Pump flow sensor *1 sec ~ 1000 samples ~16kB*



Solution: Feature Extraction

Reduce the amount of data you need to store and transmit

- 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

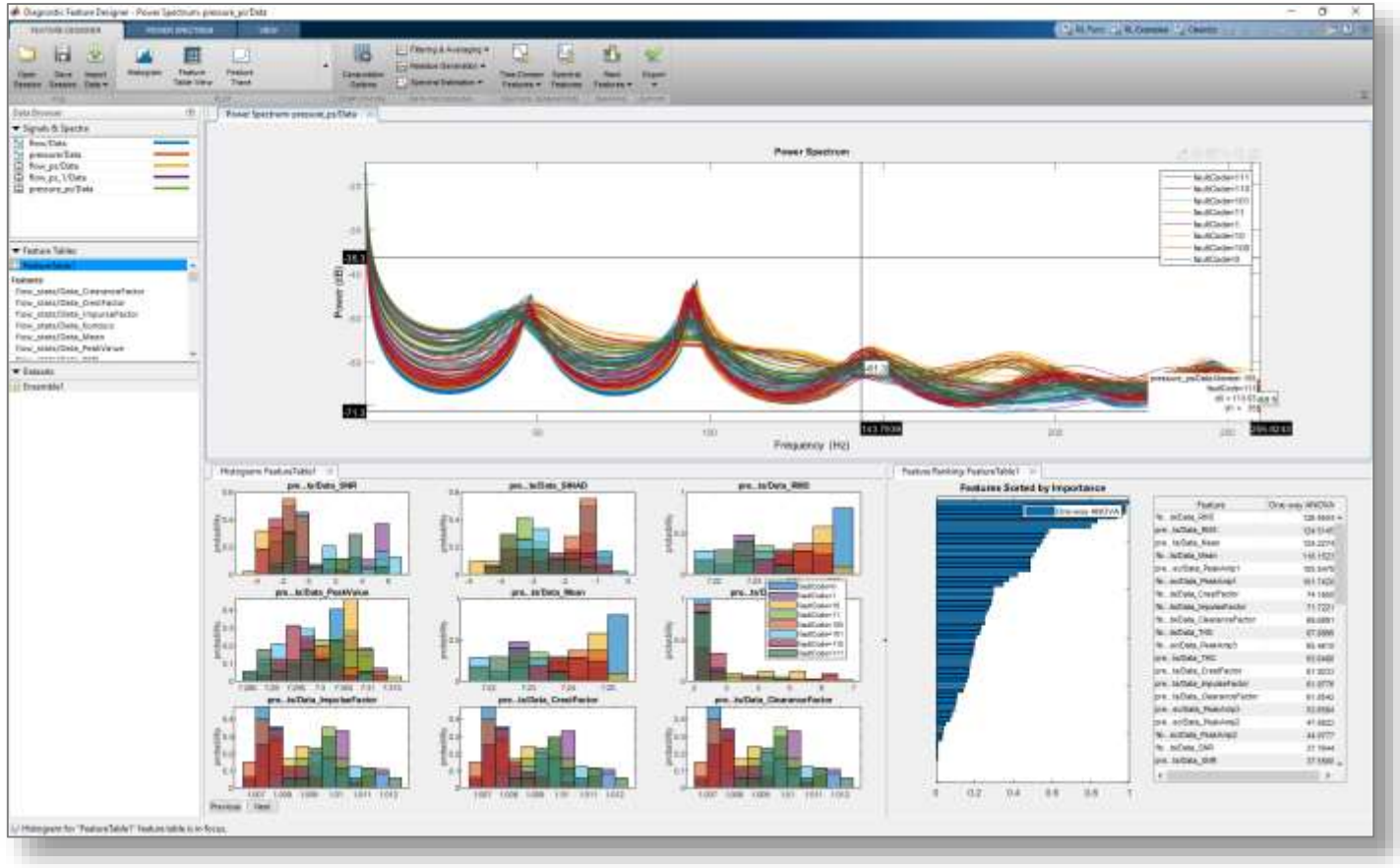


qMean	qVar	qSkewness	qKurtosis
38.4945	9.2306	-0.5728	2.4662
qPeak2P...	qCrest	qRMS	qMAD
15.2351	1.1553	38.6141	2.5562

Diagnostic Feature Designer App

Predictive Maintenance Toolbox R2019a

- Extract, visualize, and rank features from sensor data
- Use both statistical and dynamic modeling methods
- Work with out-of-memory data
- Explore and discover techniques without writing MATLAB code



Diagnostic Feature Designer - Signal Trace: flow/Data

FEATURE DESIGNER | SIGNAL TRACE | VIEW

RL Func | RL Examples | CleanUp

Open Session | Save Session | Import Data | Signal Trace | 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

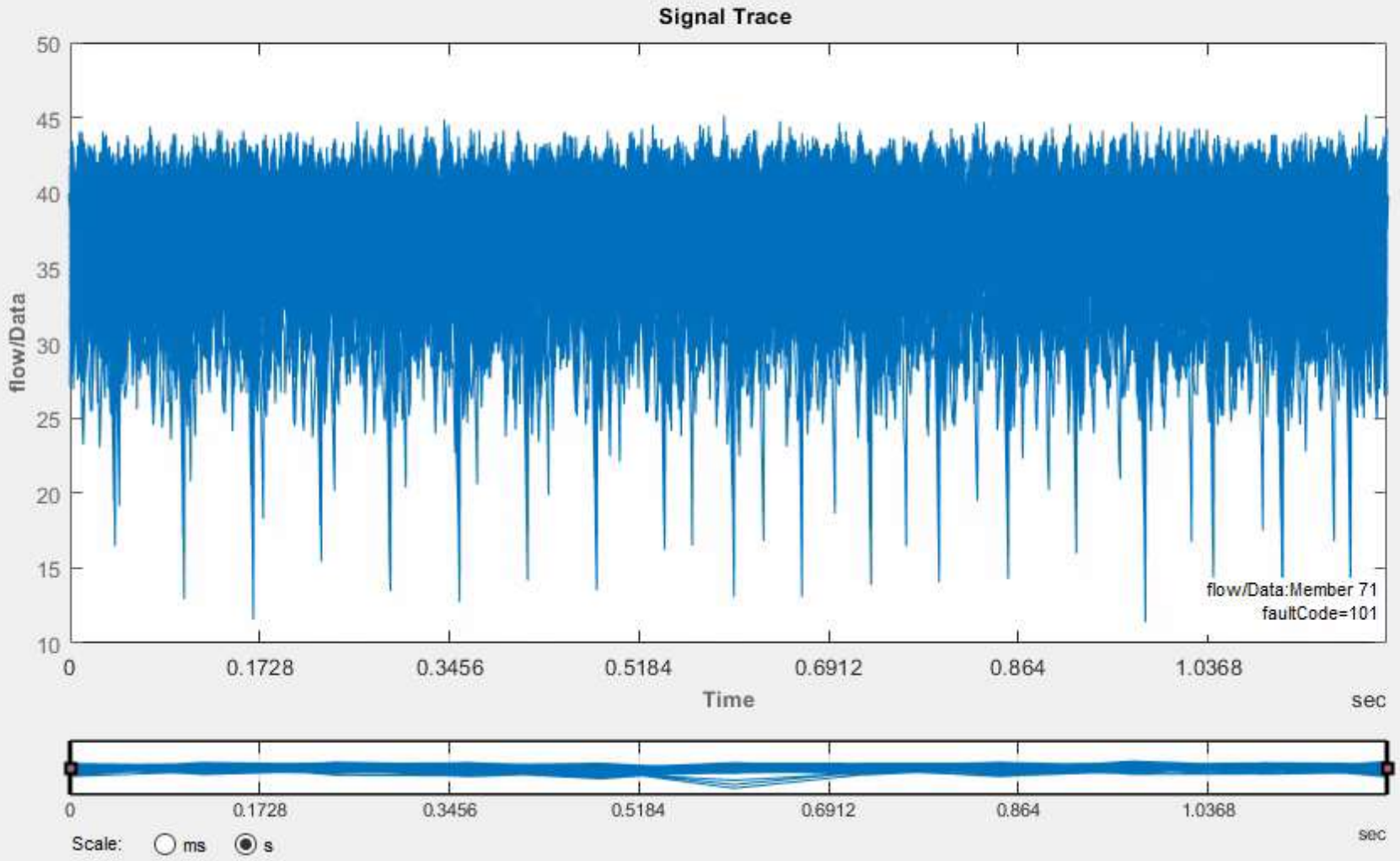
- flow/Data
- pressure/Data

Feature Tables

Datasets

- Ensemble1

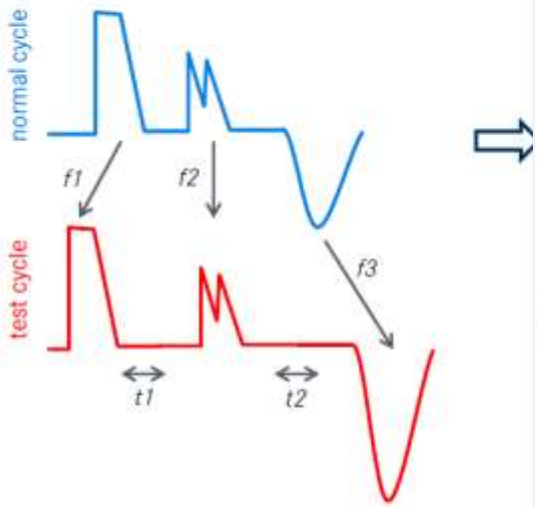
Signal Trace: flow/Data



Signal trace plot for "flow/Data" is in focus.

Daimler are Using MATLAB Today for Anomaly Detection

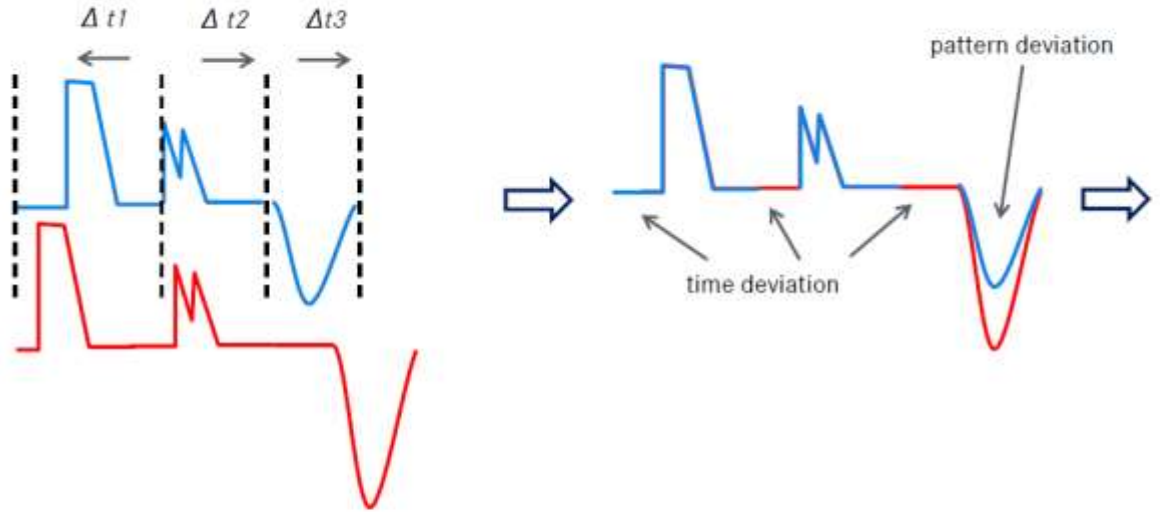
Algorithm principle



- Cycle can be described as sequence of features f1, f2, f3
- Each cycle can show some delays in time t1, t2

Mercedes-Benz Dr. Türck Ingenieurbüro Data Science

Algorithm principle



- Pattern matching through shift of feature along time axis (*Δt1, Δt2, Δt3*): minimization of SRS
- Decription of a cycle as feature sequence
- For each feature time and pattern deviation can be calculated
- Time and pattern deviation for each feature are used as characteristic numbers for test cycle

f1	*f2*	*f3*	
Δt1	*Δt2*	*Δt3*	Time deviation
No	No	Yes	Pattern deviation

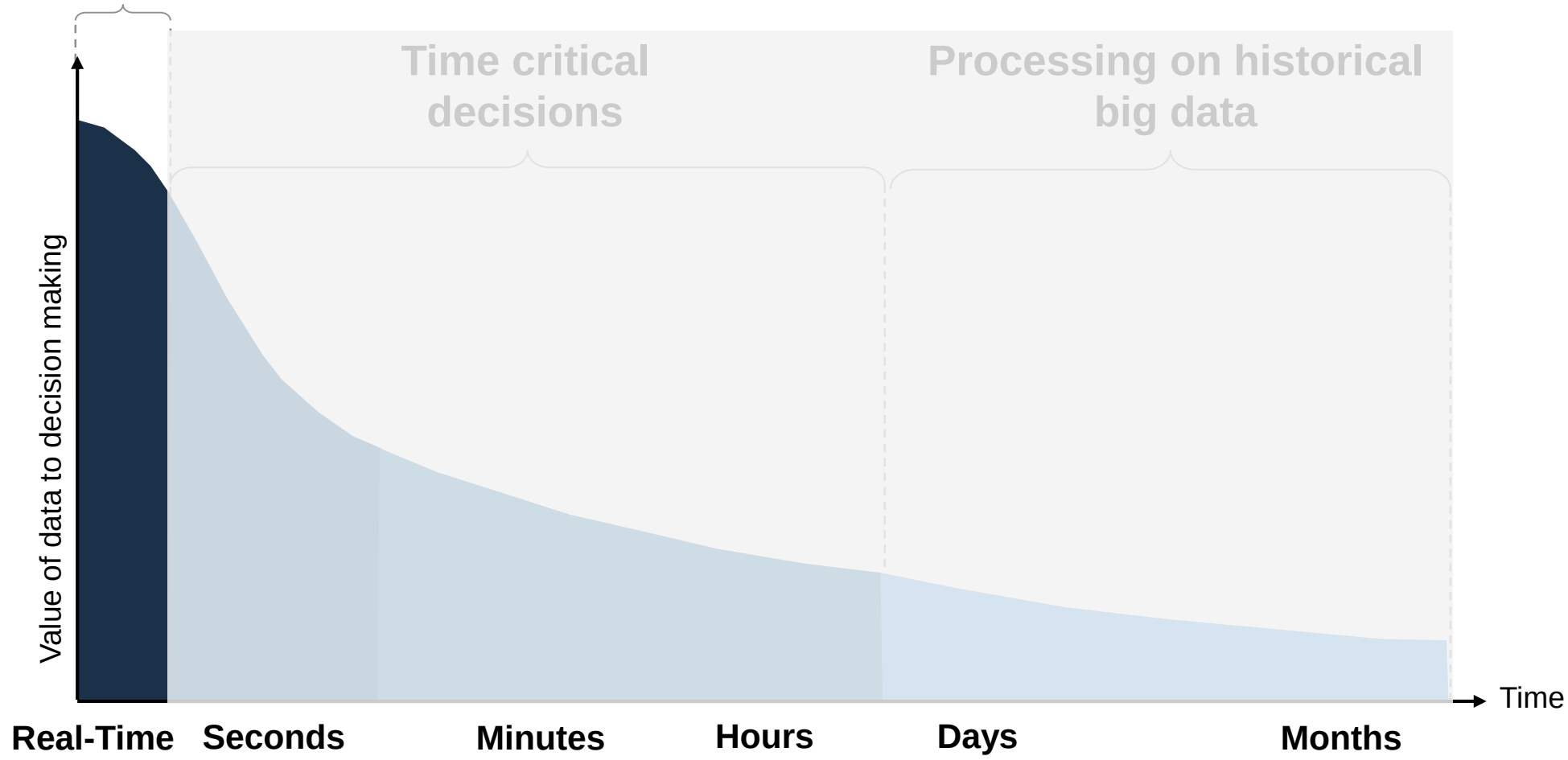
⇨ Data reduction!

Mercedes-Benz Dr. Türck Ingenieurbüro Data Science

Data reduction of time series by a factor of **250x without a significant loss of information**

When is Your Data Most Valuable?

Near real-time decisions



MATLAB R2018a

HOME | PLOTS | APPS | EDITOR | PUBLISH | VIEW

New | Open | Save | Find Files | Compare | Print | Go To | Find | Insert | Comment | Indent | Breakpoints | Run | Run and Advance | Run Section | Advance | Run and Time

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

Current Folder

Name

- Folder
  - codegen
  - Copy_of_Data
  - Data
- Function
  - featureExtraction.m
  - featureExtractionBuffer.m
  - helperSortedBarPlot.m
  - monotonicity.m
- MEX-file
  - featureExtraction_mex.mexw64
  - featureExtractionBuffer_mex.mexw64
- Live Script
  - Expo_Data_Preprocessing_CodeGe...
- MATLAB Coder Project
  - featureExtraction.prj
  - featureExtractionBuffer.prj

featureExtractionBuffer.m (Function)

Editor - C:\Users\abaru\Desktop\Expo 2018\FinalDemo\Demo_Files\Data_Reduction\featureExtractionBuffer.m

Expo_Data_Preprocessing_CodeGen.mlx | featureExtractionBuffer.m

```
1   function [feature_list] = featureExtractionBuffer(data,timestamp)
2
3   persistent flow_array
4   persistent time_array
5   Np = 1000;
6
7   if isempty(flow_array)
8       flow_array = nan(Np,1);
9   end
10
11  if isempty(time_array)
12      time_array = nan(Np,1);
13  end
14
15  flow_array = [data; flow_array(1:Np-1)];
16  data = flow_array;
17
18  time_array = [timestamp; time_array(1:Np-1)];
19  timestamp = time_array;
20
21
22  if isempty(find(isnan(data),1))
23
24      flow = data;
25
26      % Ensure the flow is sampled at a uniform sample rate
27      t_flow = timestamp;
```

featureExtractionBuffer | Ln 17 Col 1

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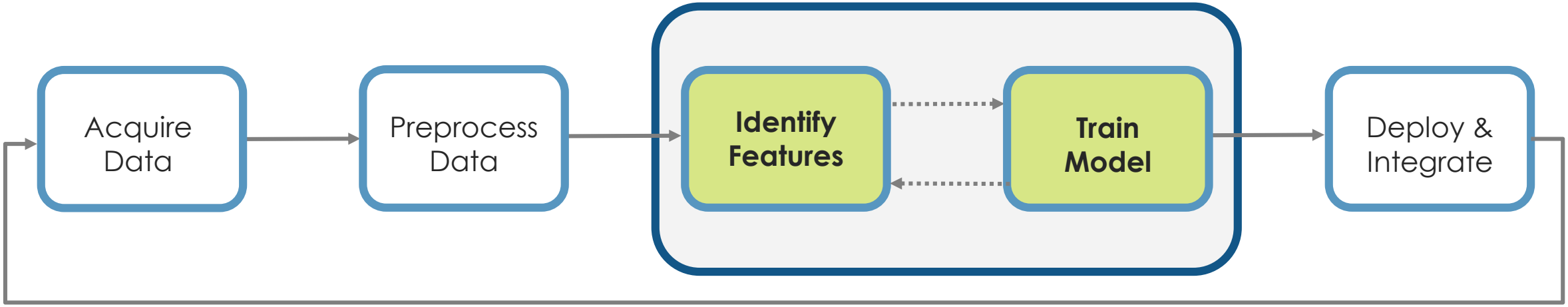
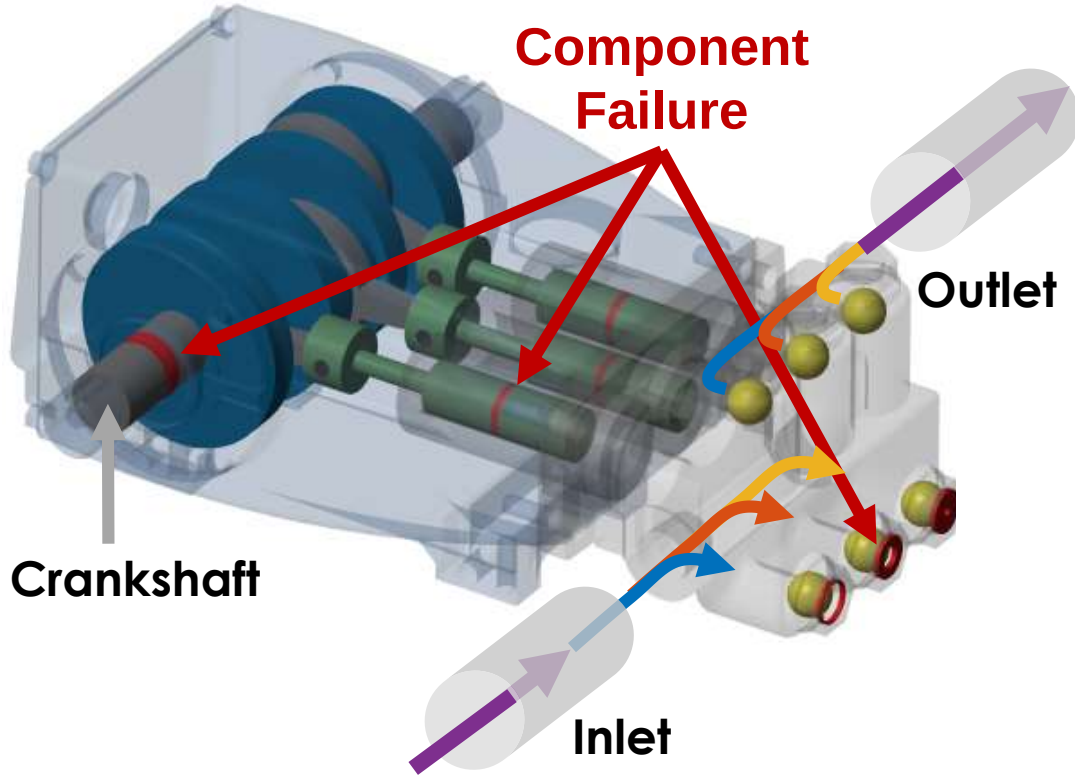


Fault Classification Algorithms Allow You to Identify the Root Cause of Anomalous Behavior

- Three-phase pump commonly used for drilling and servicing oil wells
  - Three plungers try to ensure a uniform flow
- Condition monitoring to detect:
  - Seal leak
  - Inlet blockage
  - Bearing degradation



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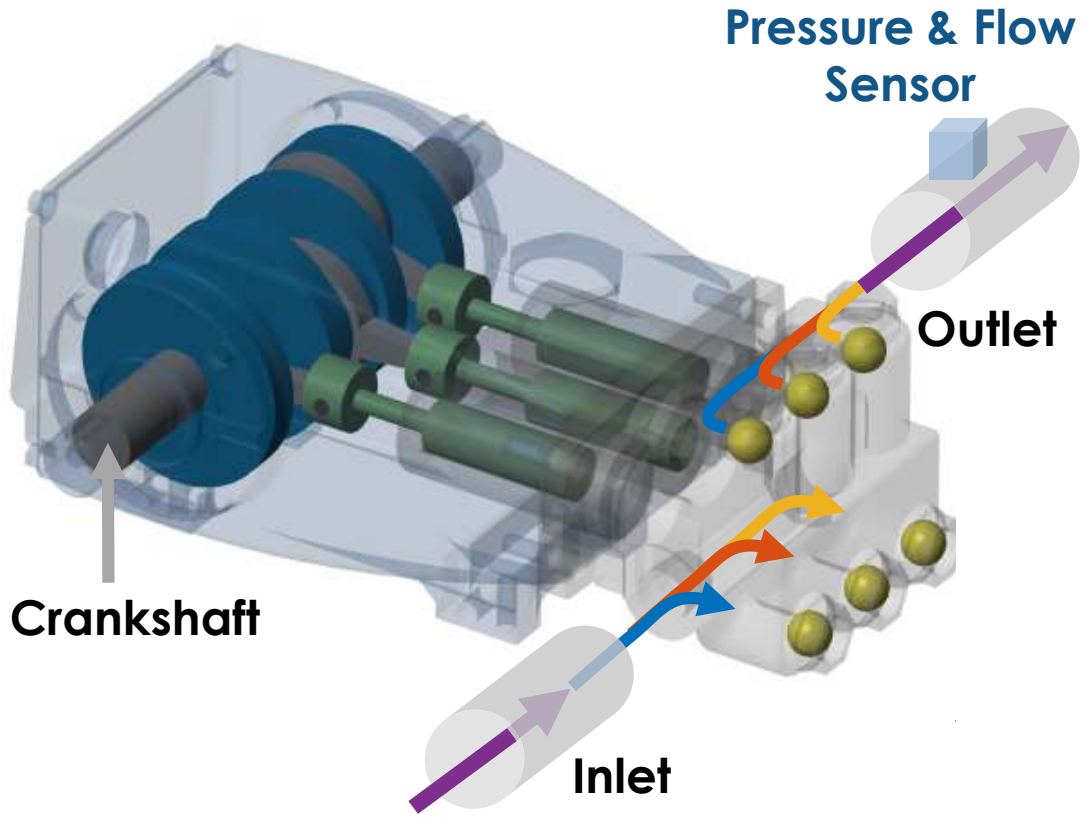
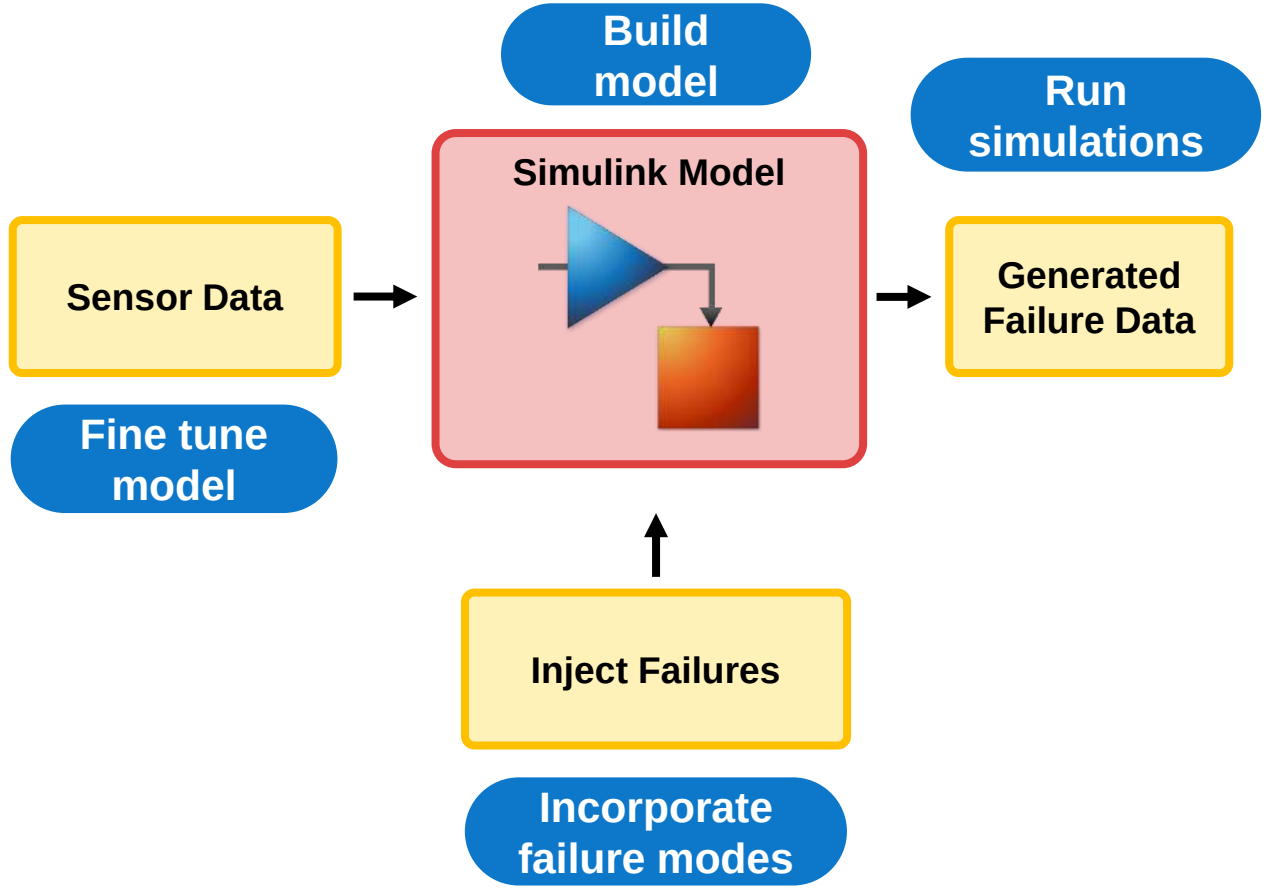
  - Inlet blockage
  - Bearing degradation
- Identify fault present in system using **only** pressure and flow sensor data



Generate Synthetic Failure Data from Simulink Models if Real Failure Data is Unavailable

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



Diagnostic Feature Designer - Signal Trace: flow/Data

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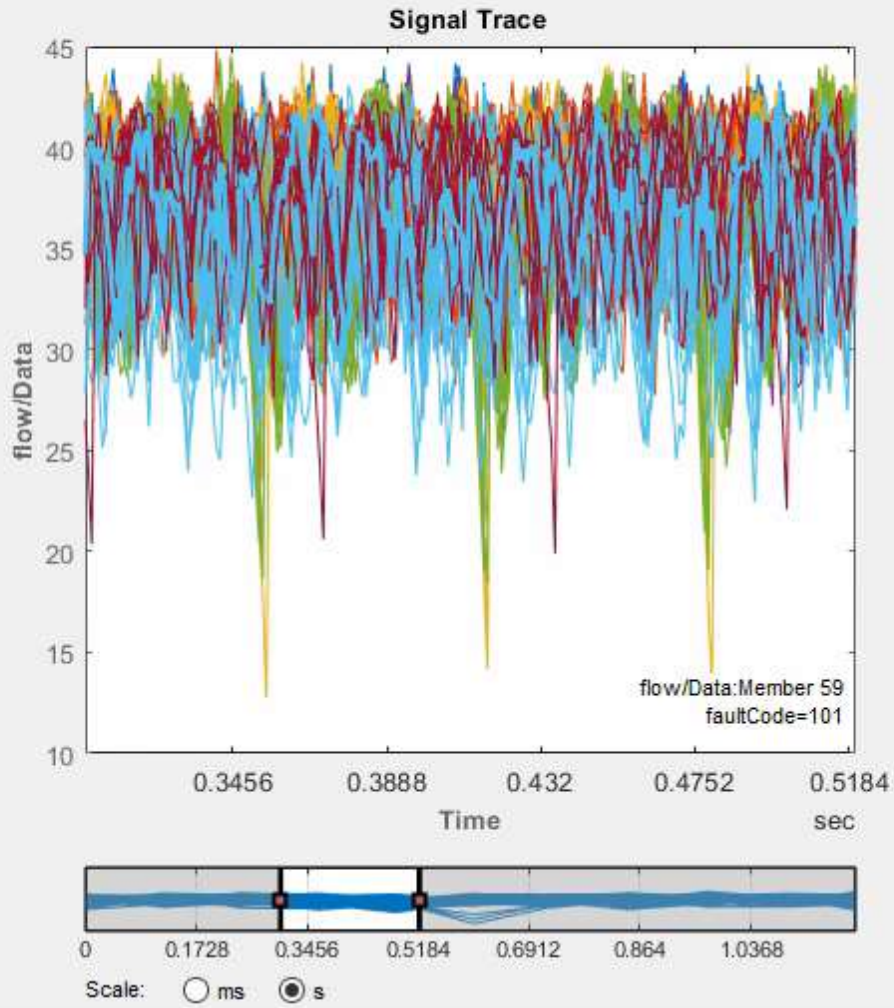
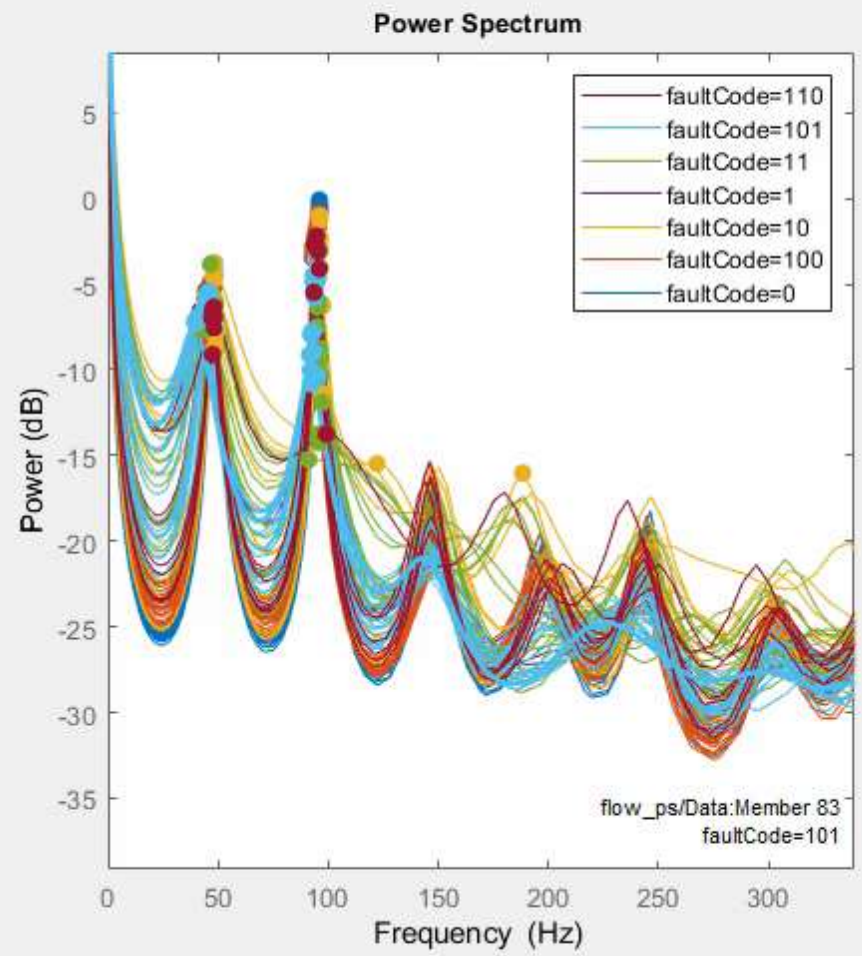
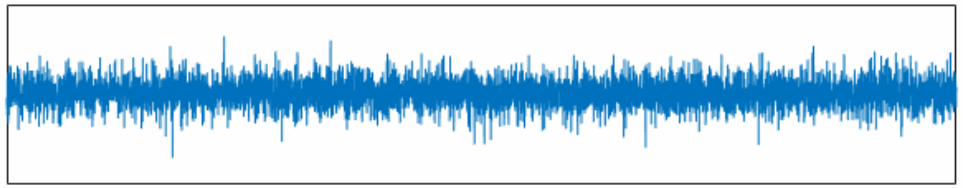


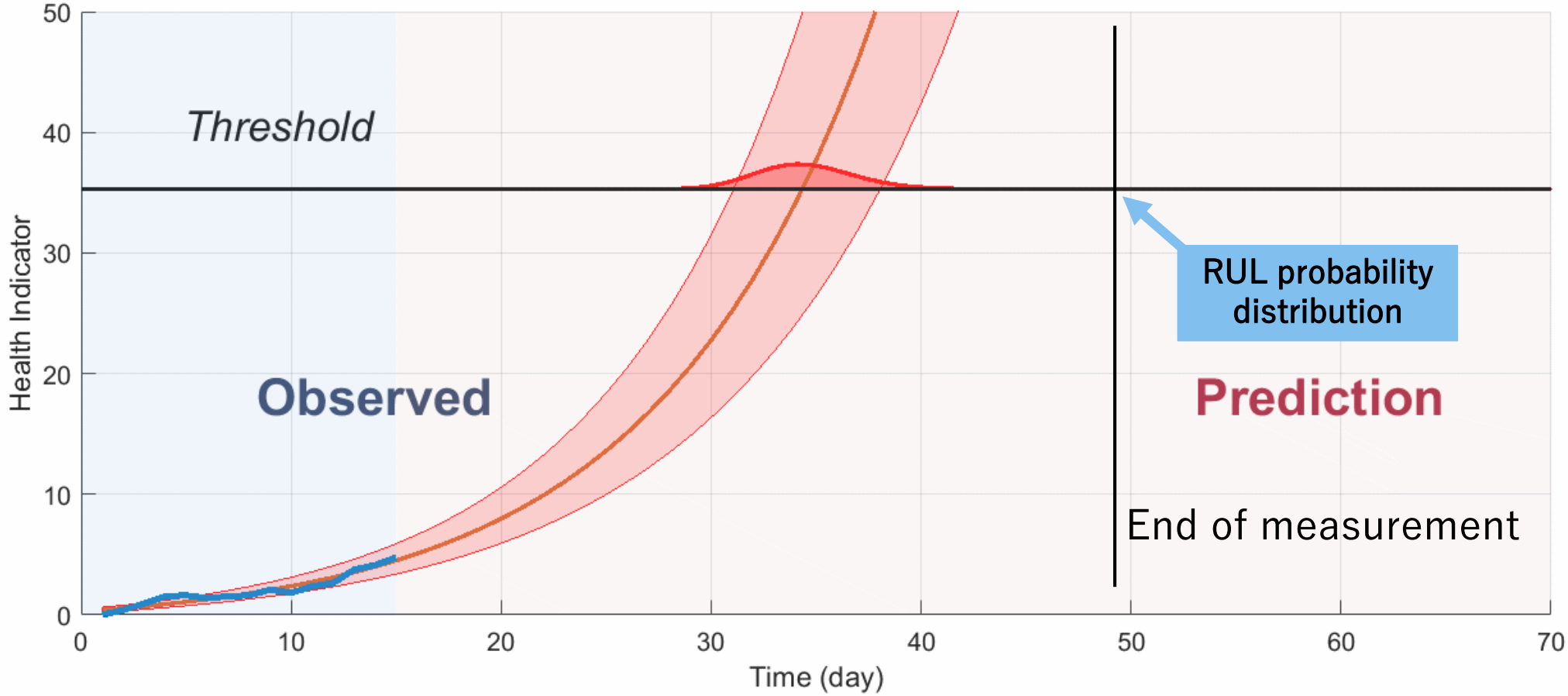
Power Spectrum: flow_ps/Data



Estimate Remaining Useful (RUL) to Determine When You Should Perform Maintenance



RUL: 459 hours
(95%CI: 374-558 hours)



Baker Hughes Develops Predictive Maintenance Software for Gas and Oil Extraction

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 machine learning model that can predict 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.

"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

Link to user story

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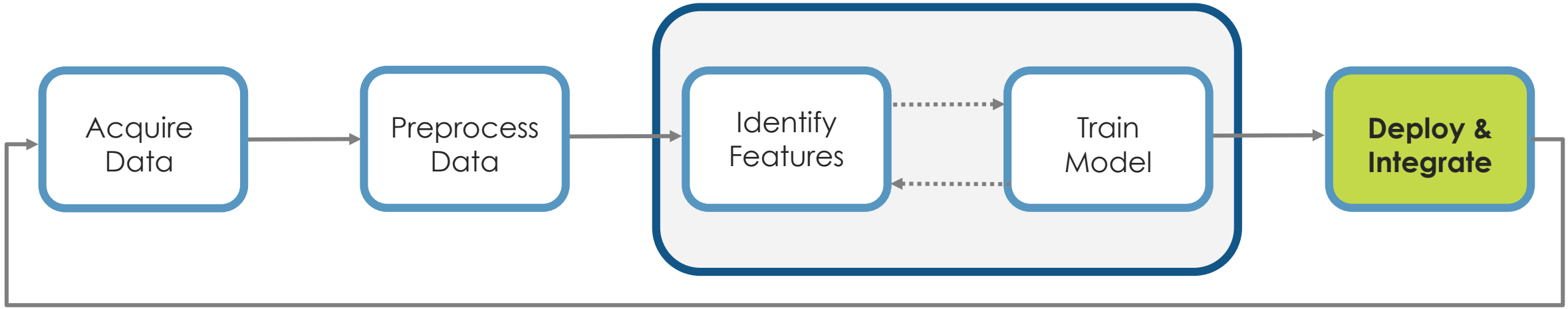
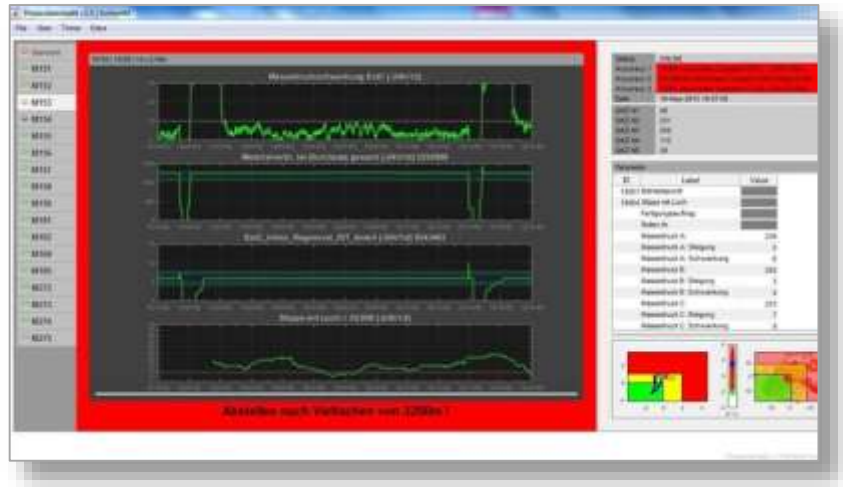
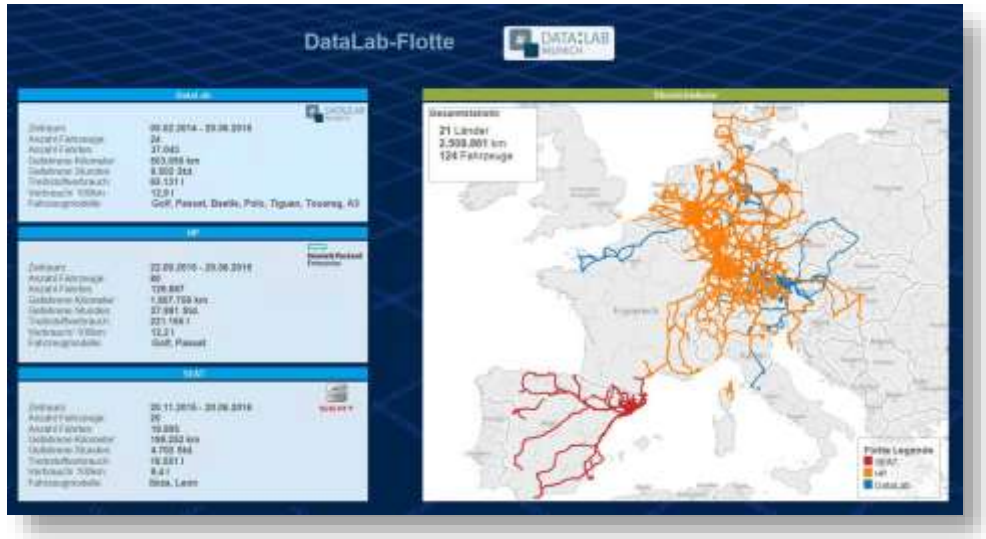


Challenges: Delivering results to your end users

- 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

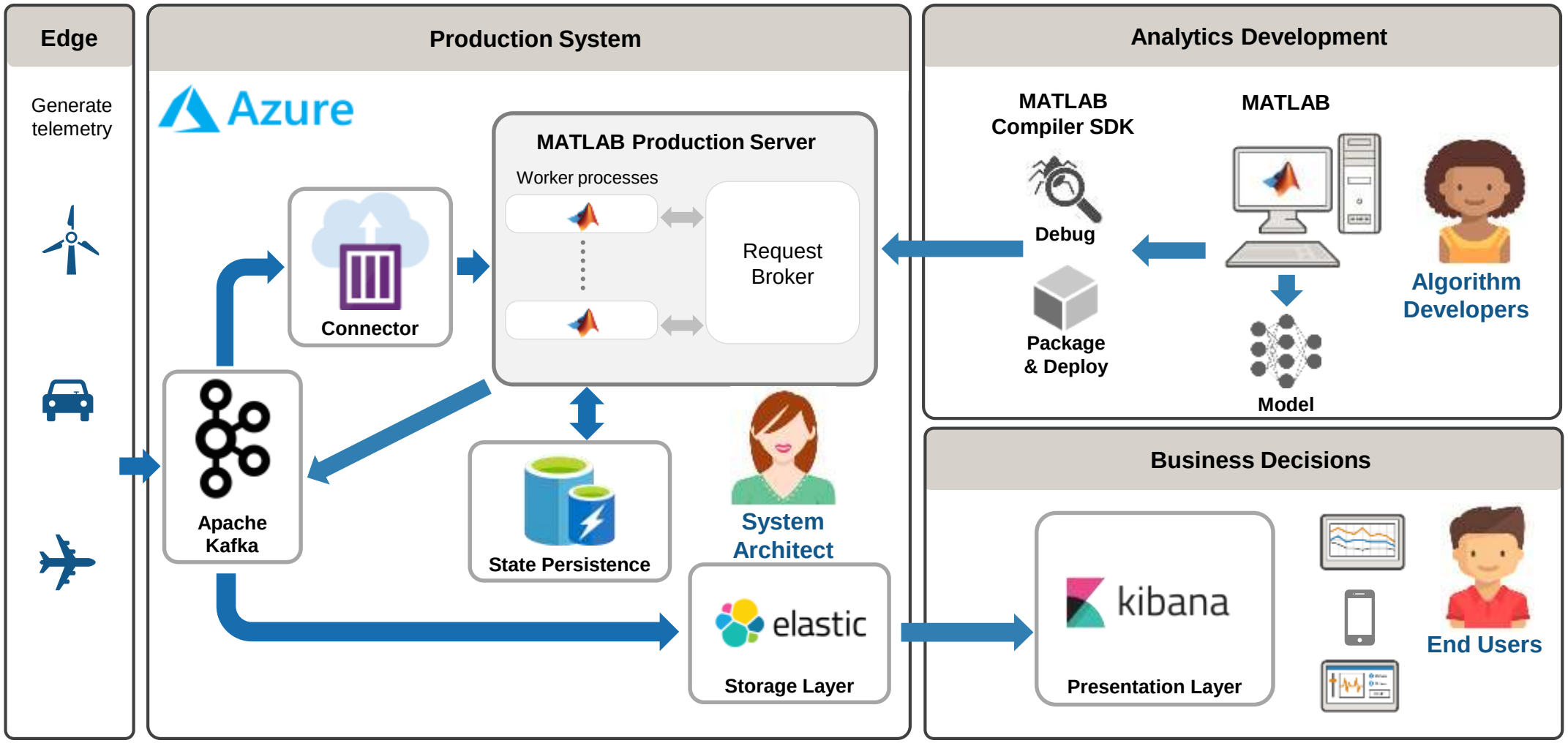


Dashboards



Fleet & Inventory Analysis

Predictive Maintenance Architecture on Azure



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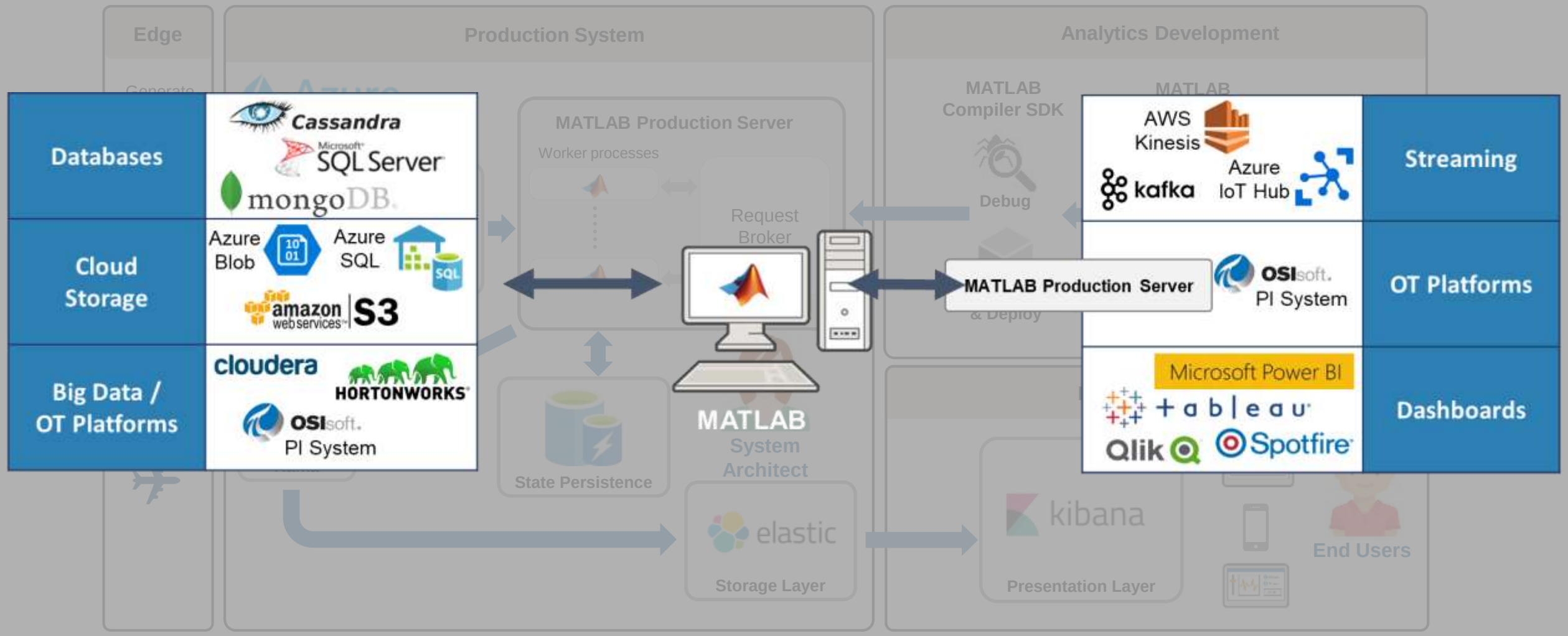
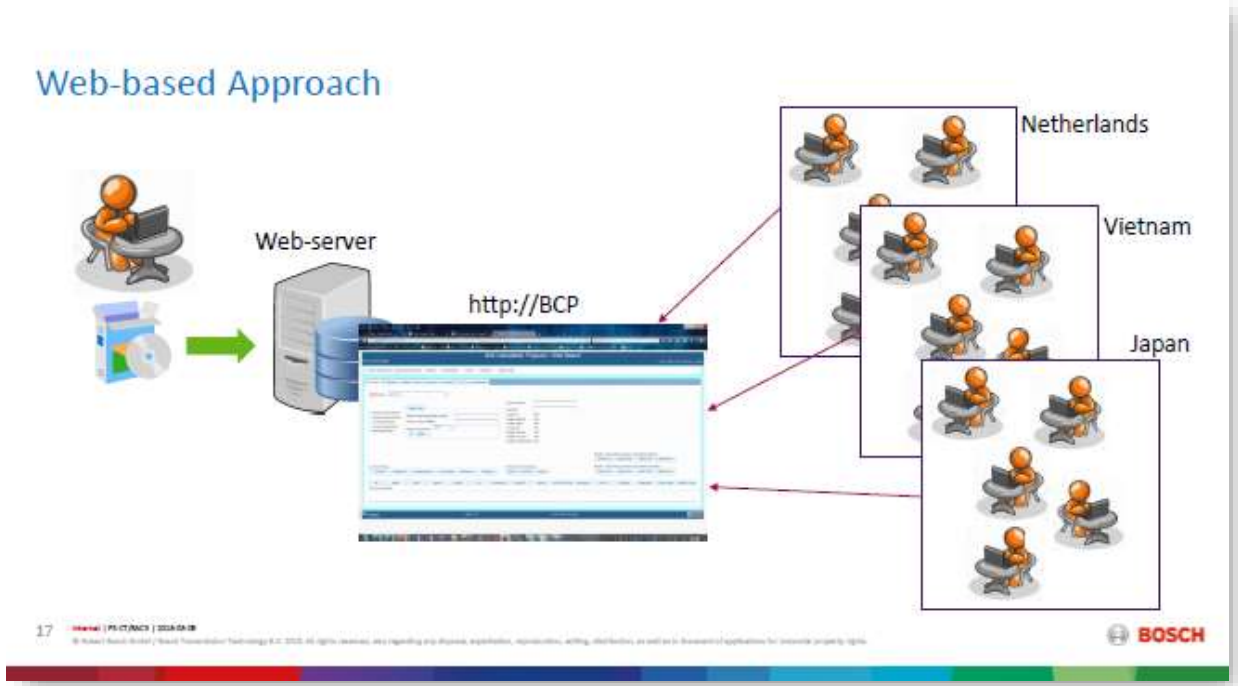
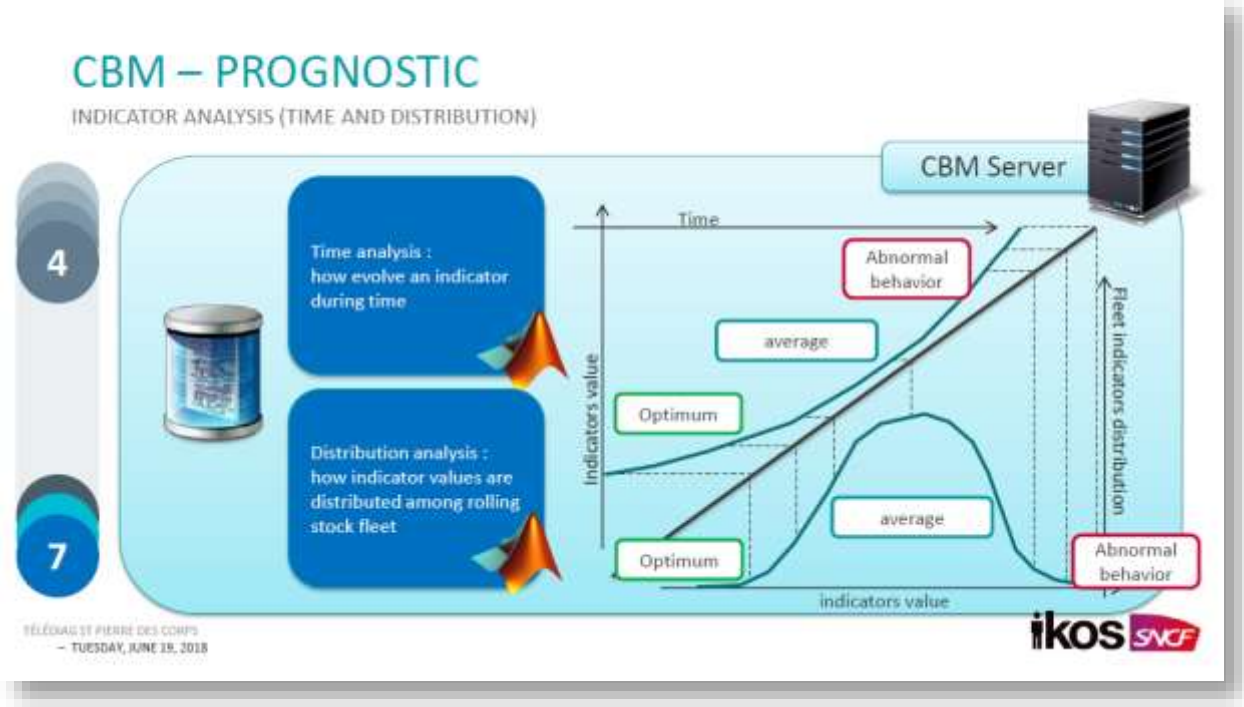


Bosch and SNCF Have Implemented Production Systems Running Today



Link to user story

“Updating software is required only at 1 location…Maximum of 1 hour downtime for major updates…”



Link to user story

“…[Our solution] optimizes the whole maintenance process without breaking the existing process…”

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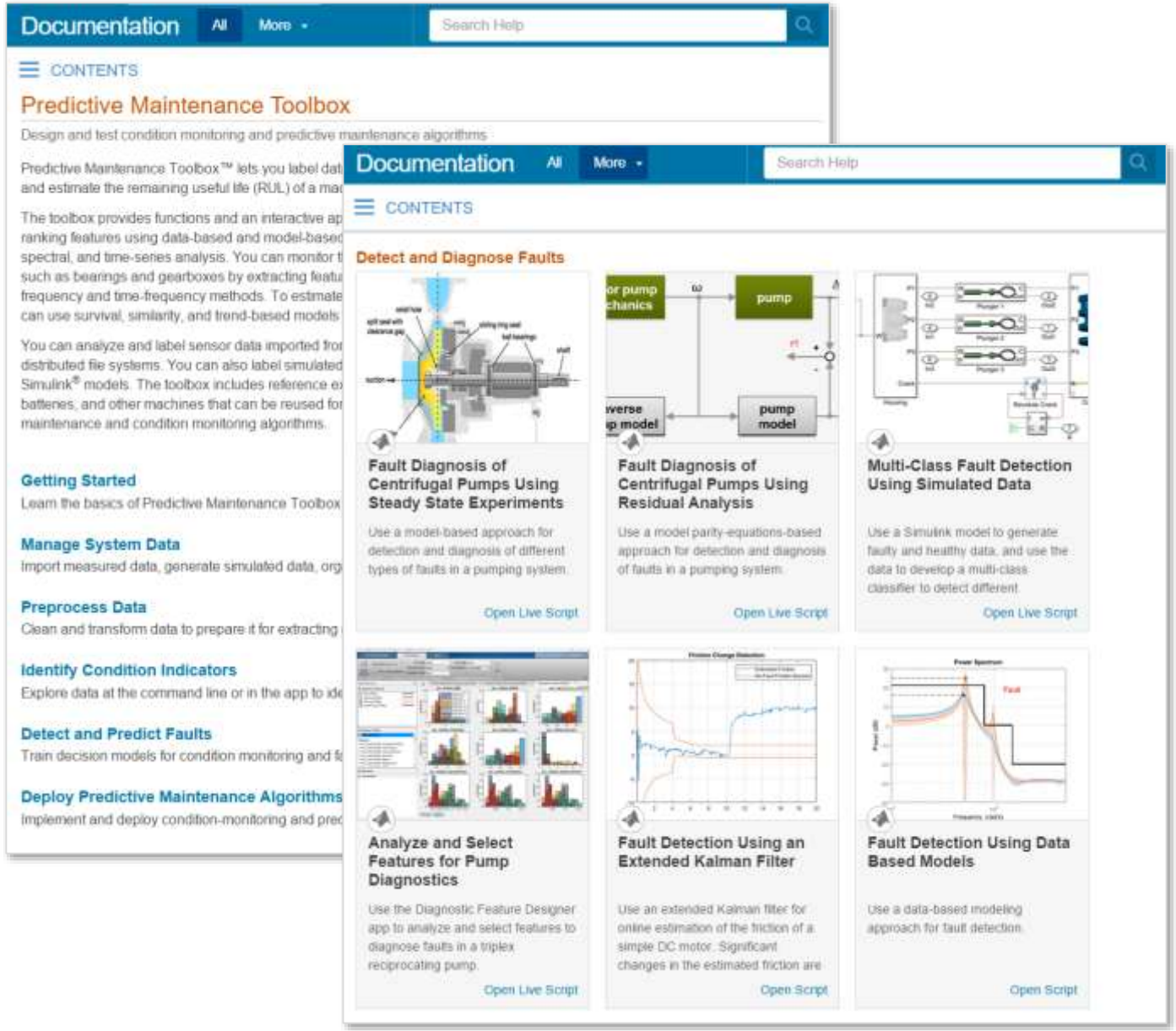
MathWorks can help you get started TODAY

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



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