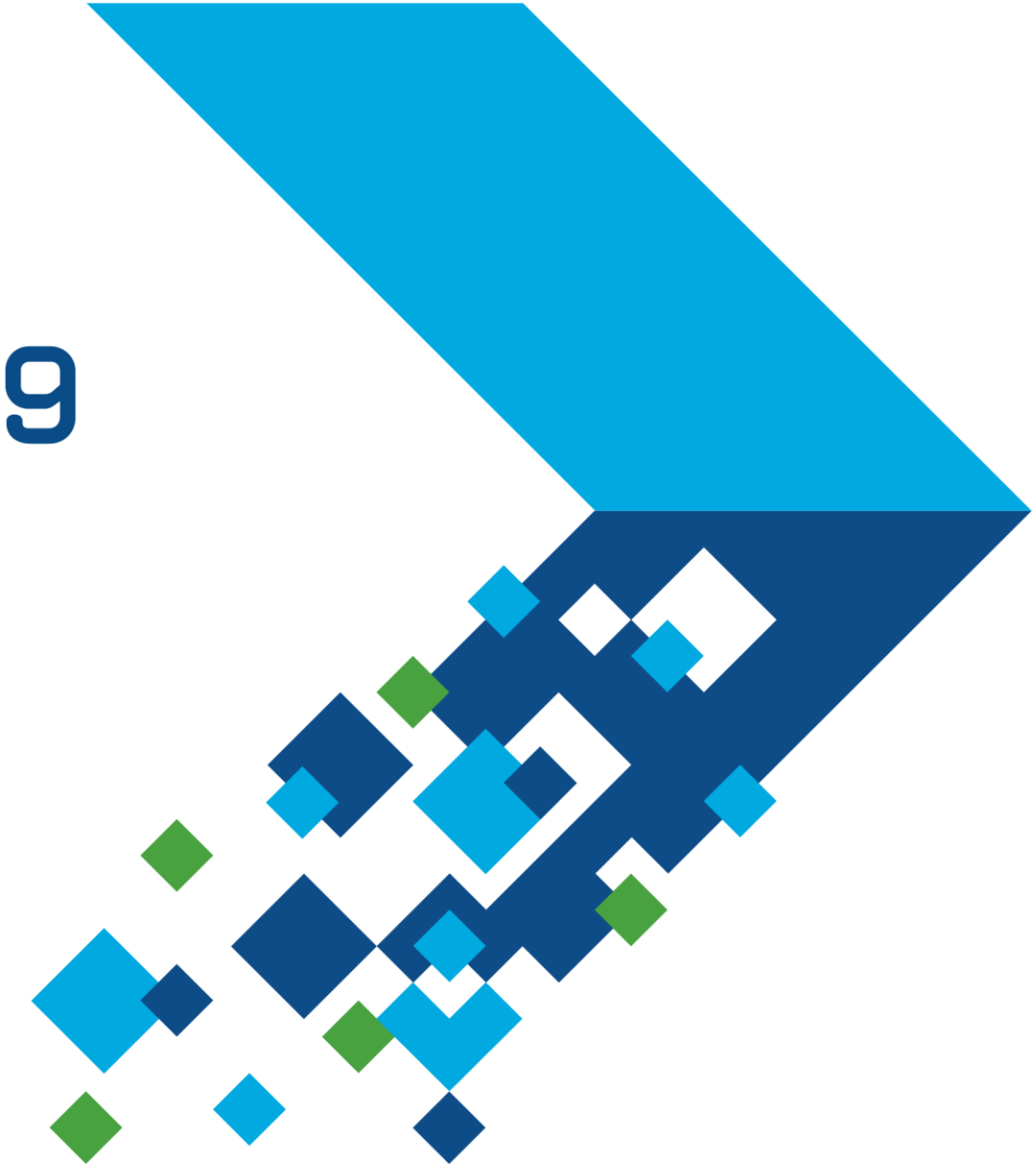
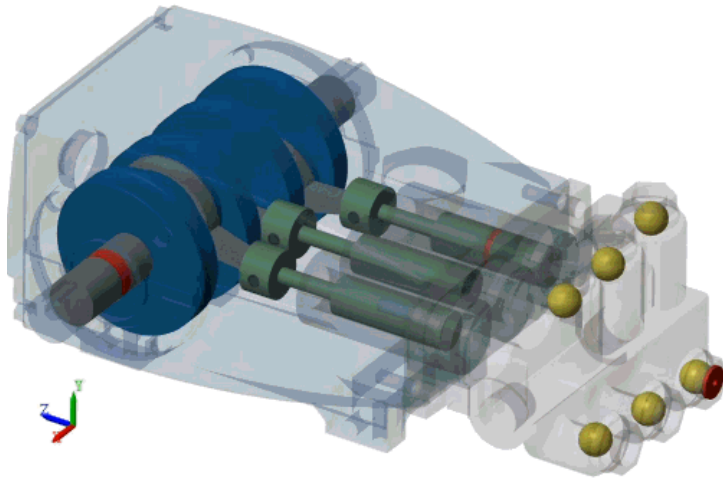
MATLAB EXPO 2019

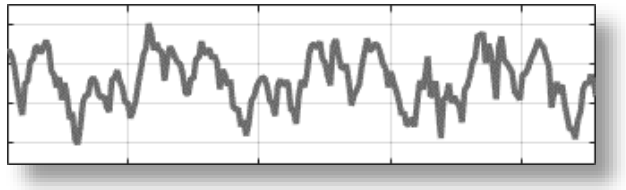
Manutenzione Predittiva con MATLAB

Francesco Alderisio



What is Predictive Maintenance?





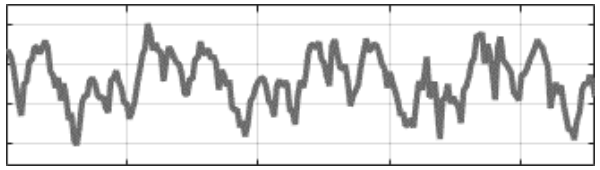
Translate

Turn off instant translation

English | Spanish | French | Pump - detected

English | Russian | Greek

Translate



1/5000

I need help.

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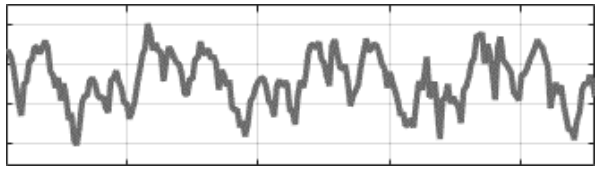
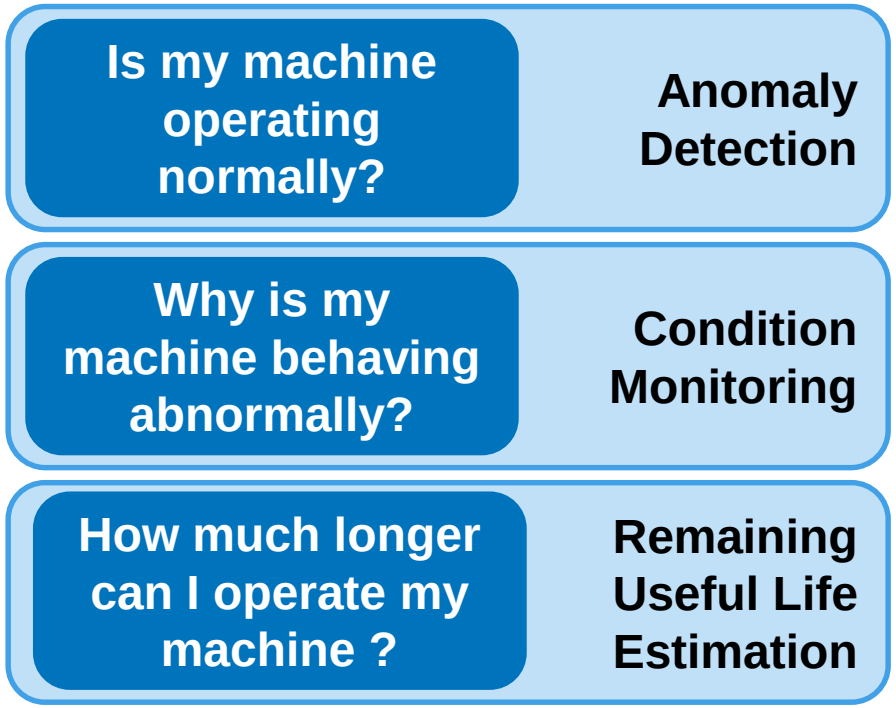


1/5000

I need help. One of my cylinders is blocked. Your pump might fail in 15 hours

What Does a Predictive Maintenance Algorithm Do?



I need help.

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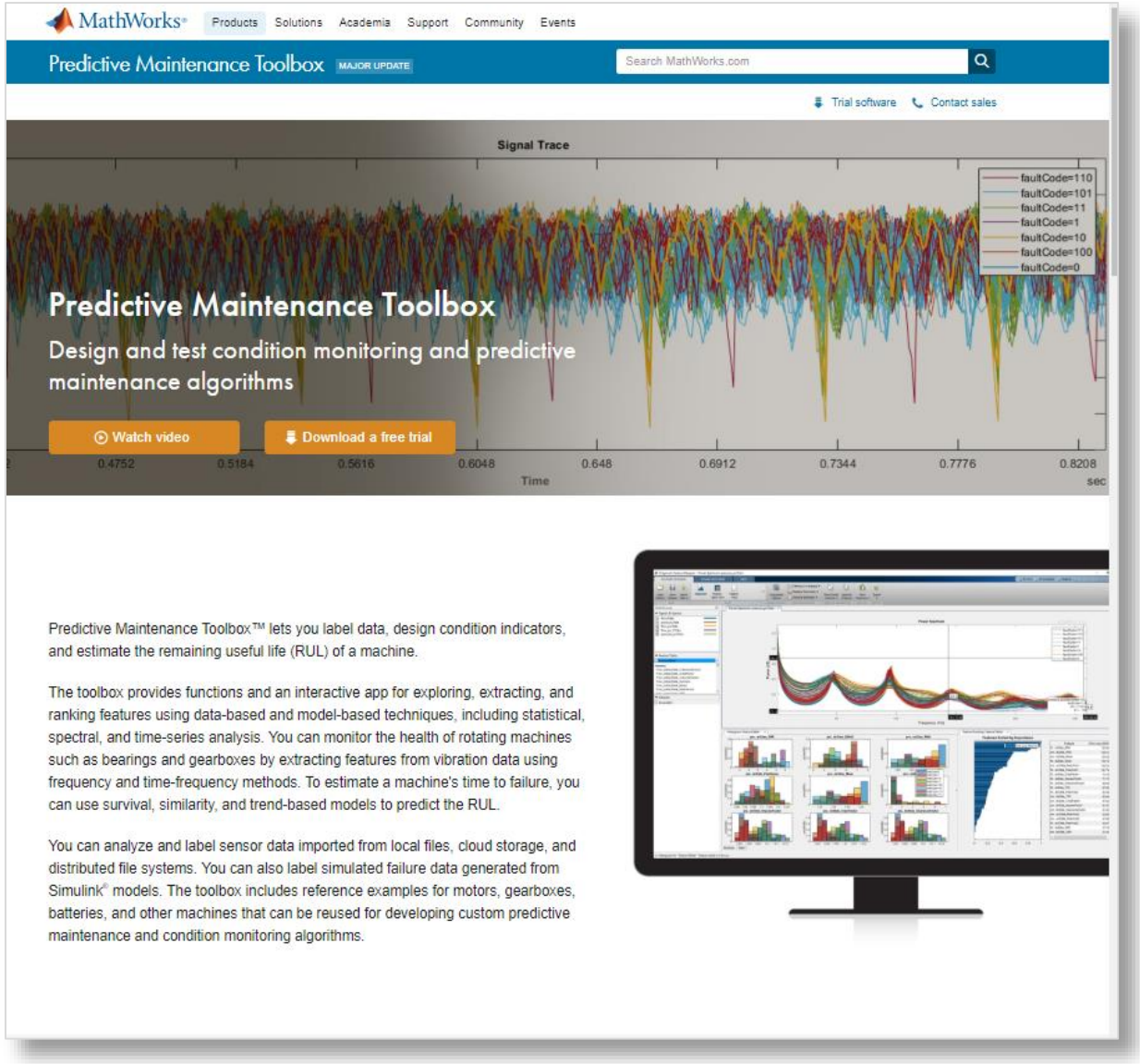
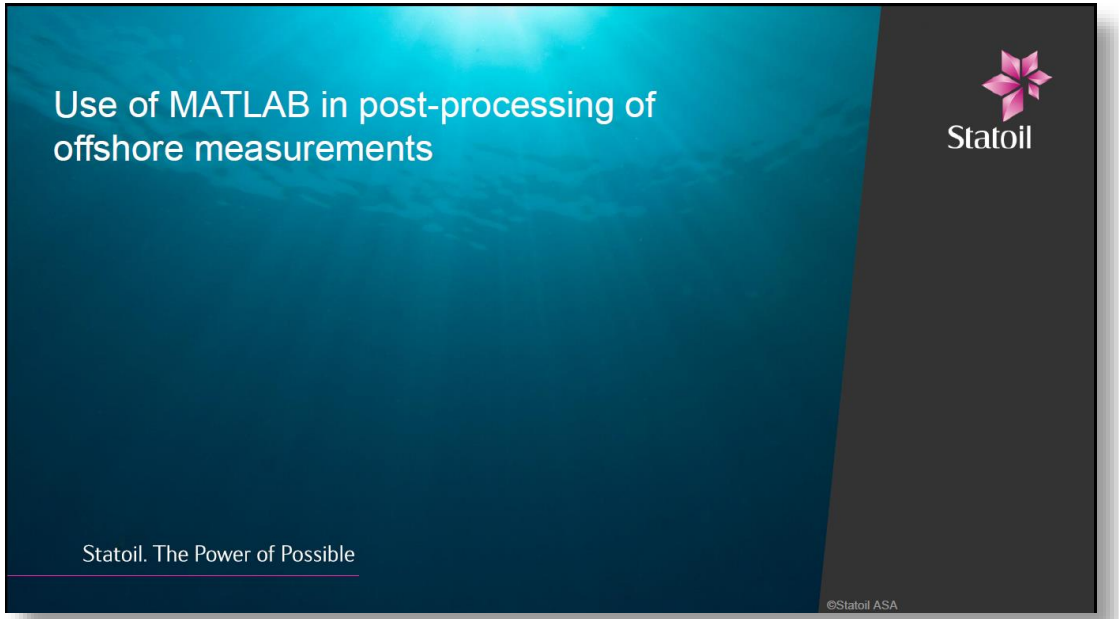
Predictive Maintenance Toolbox for Developing Algorithms

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



How are MathWorks Tools Used for Predictive Maintenance?



"…Subject Matter Expert Familiarity…"

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

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SNCF

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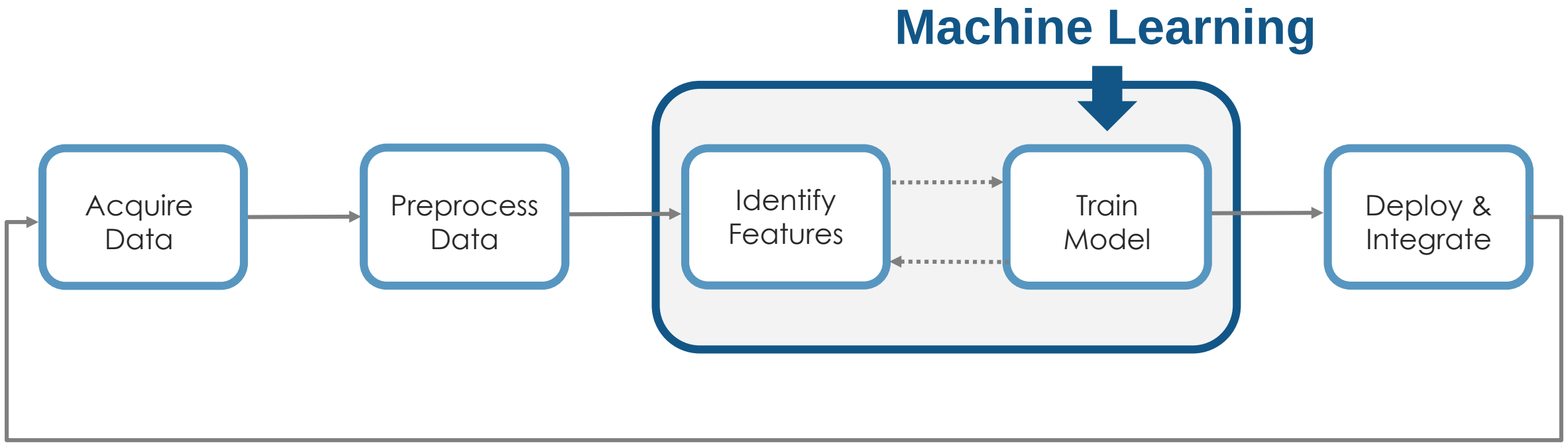
BOSCH

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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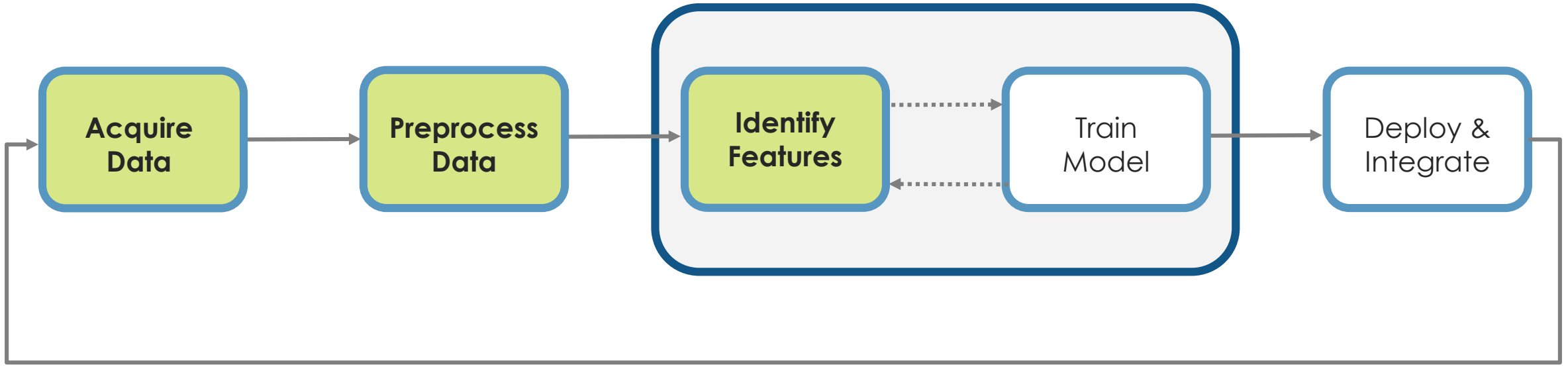
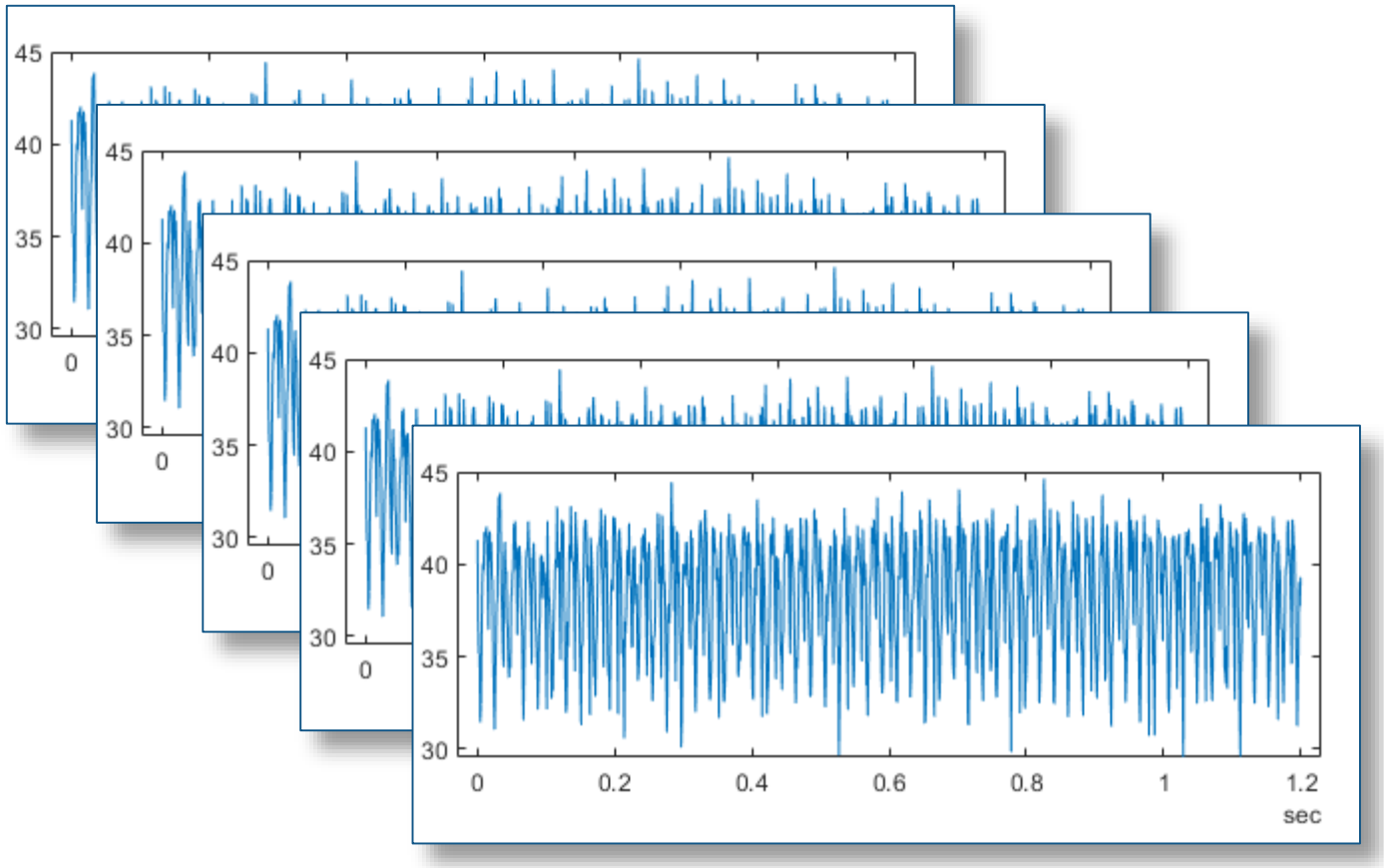


Challenges: How do you make sense of the ALL the data being collected?

- 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

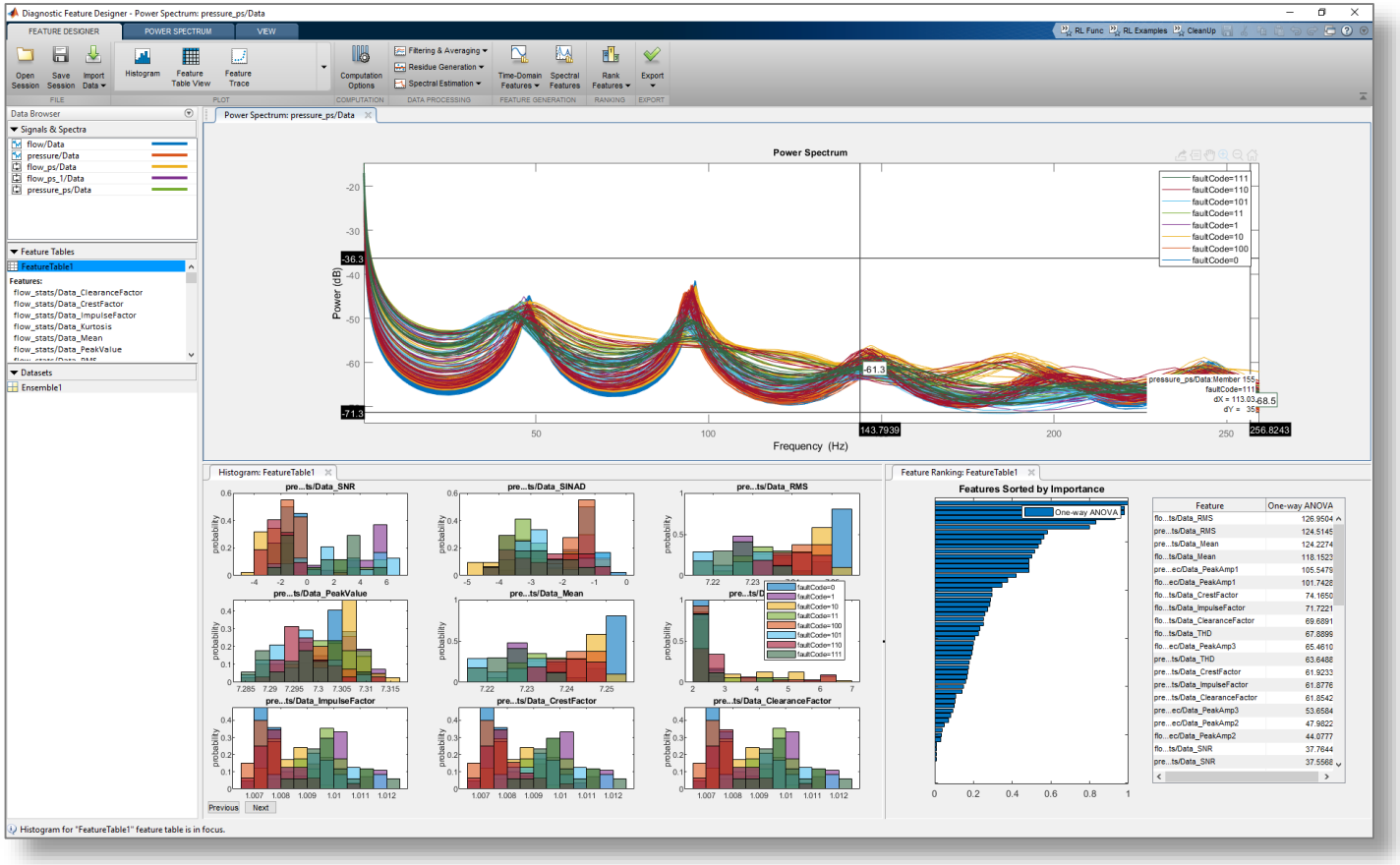
Pump flow sensor *1 sec ~ 1000 samples ~16kB*



Diagnostic Feature Designer App

Predictive Maintenance Toolbox R2018b & 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

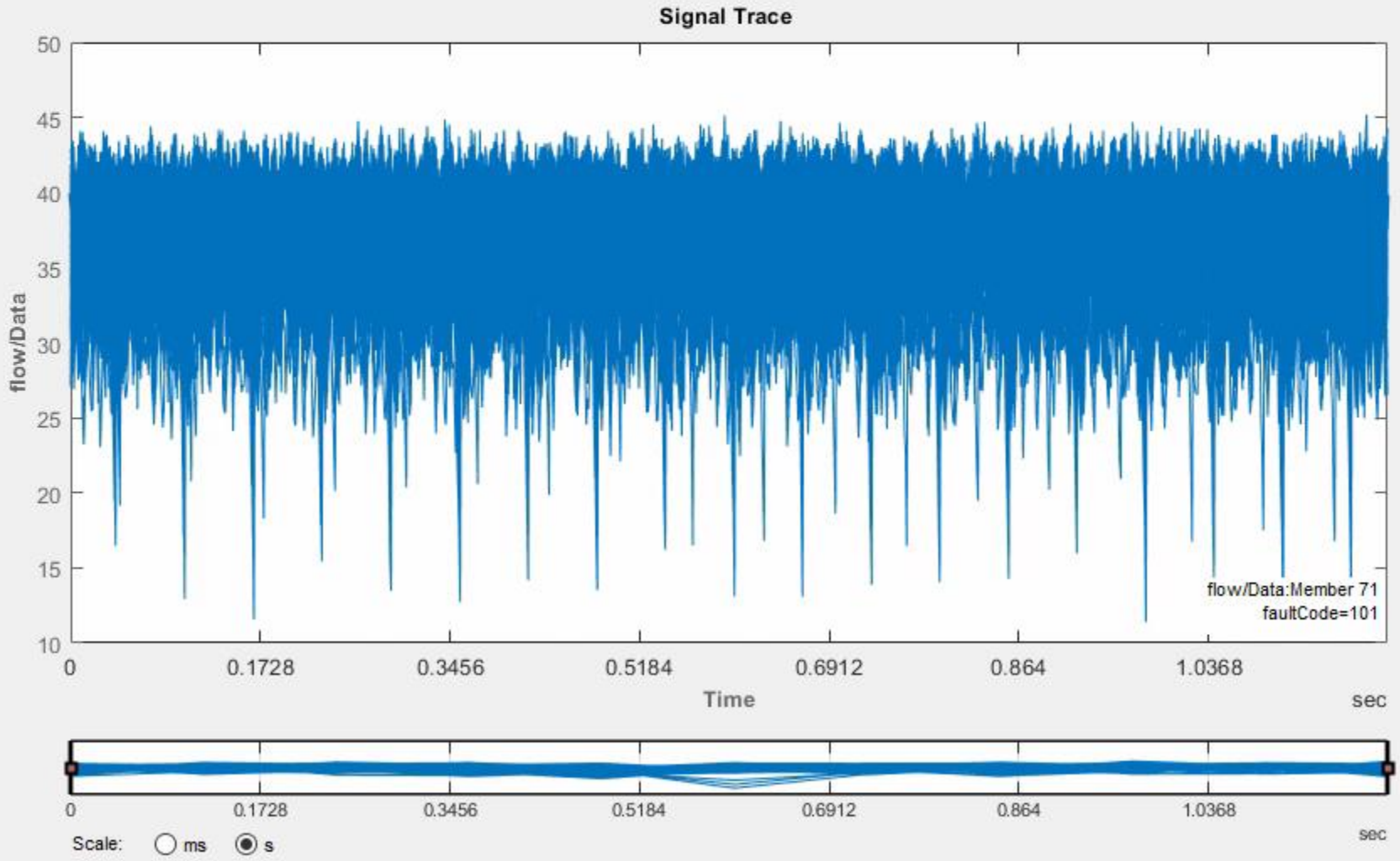
- flow/Data
- pressure/Data

Feature Tables

Datasets

- Ensemble1

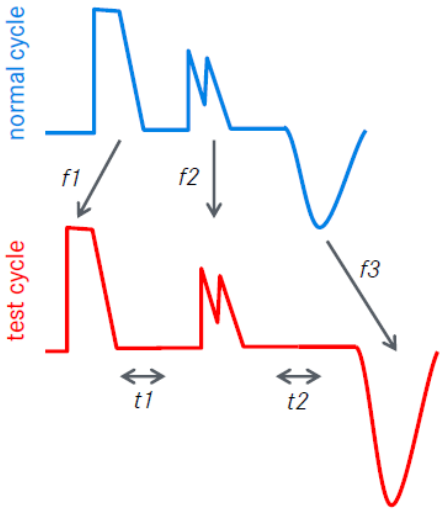
Signal Trace: flow/Data



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

Daimler are Using MATLAB Today for Anomaly Detection

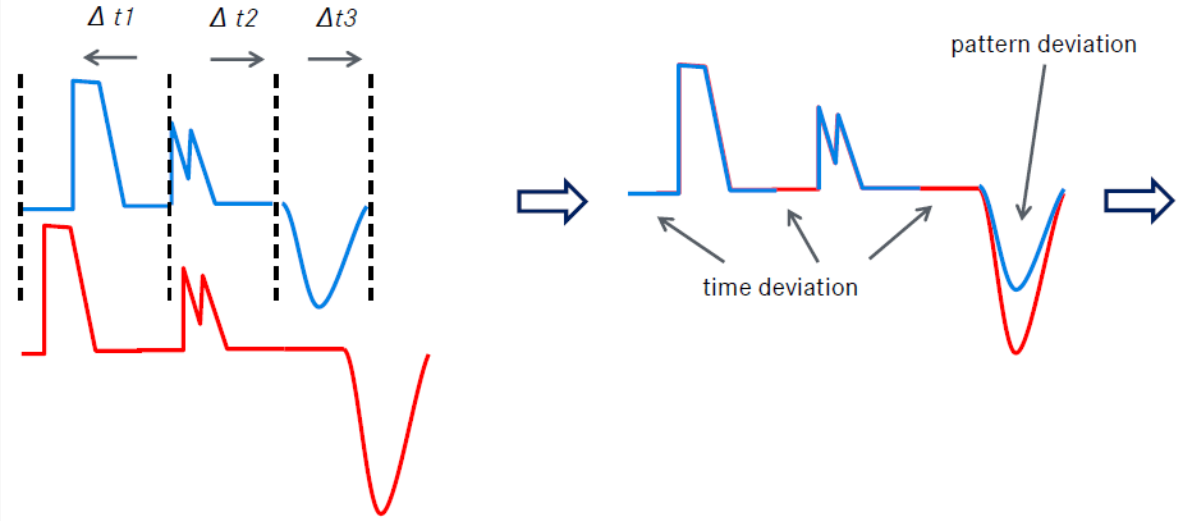
Algorithm principle



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

Mercedes-Benz | Dr. Türck Ingenieurbüro Data Science

Algorithm principle



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

- 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

⇨ Data reduction!

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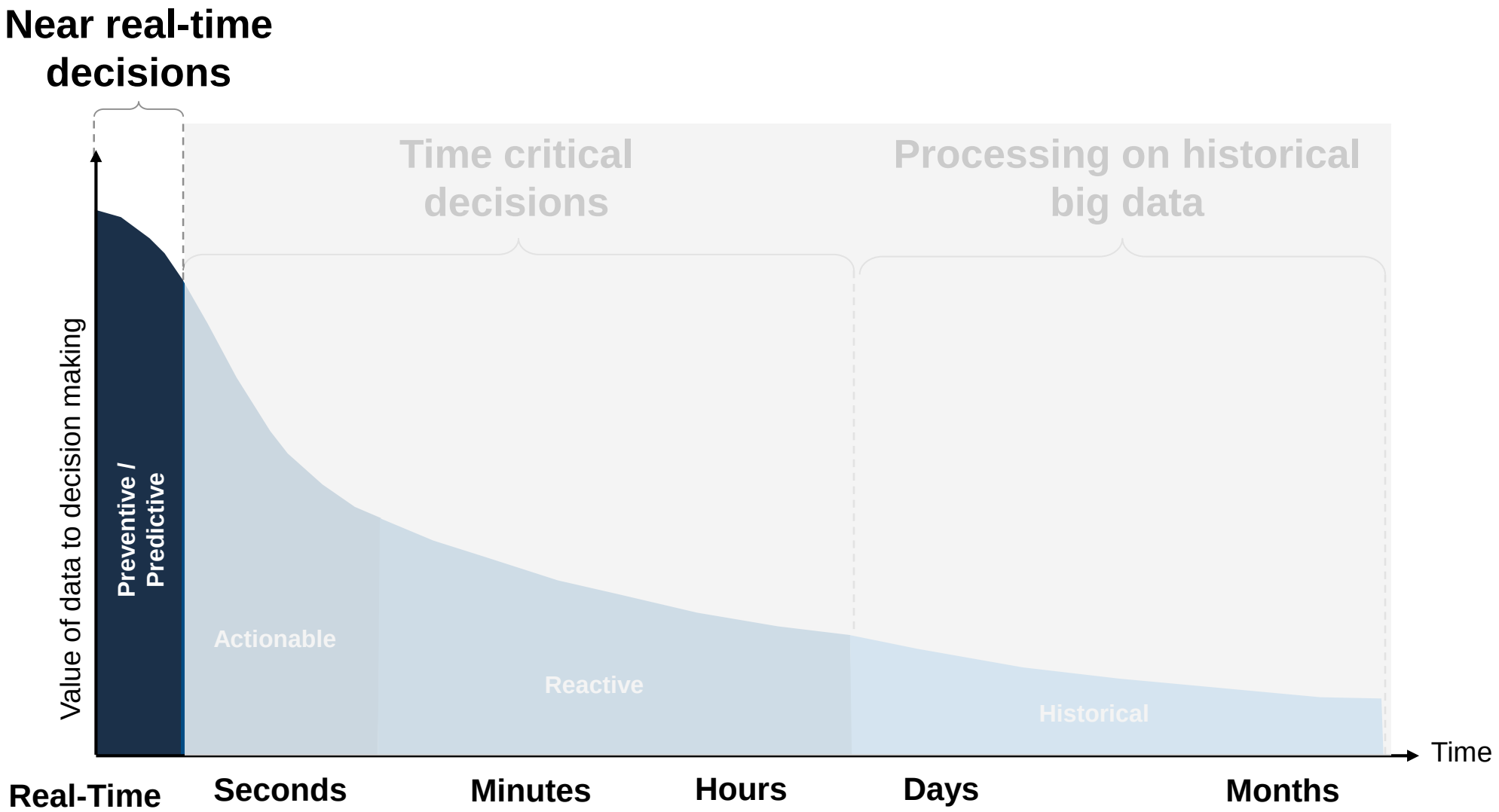
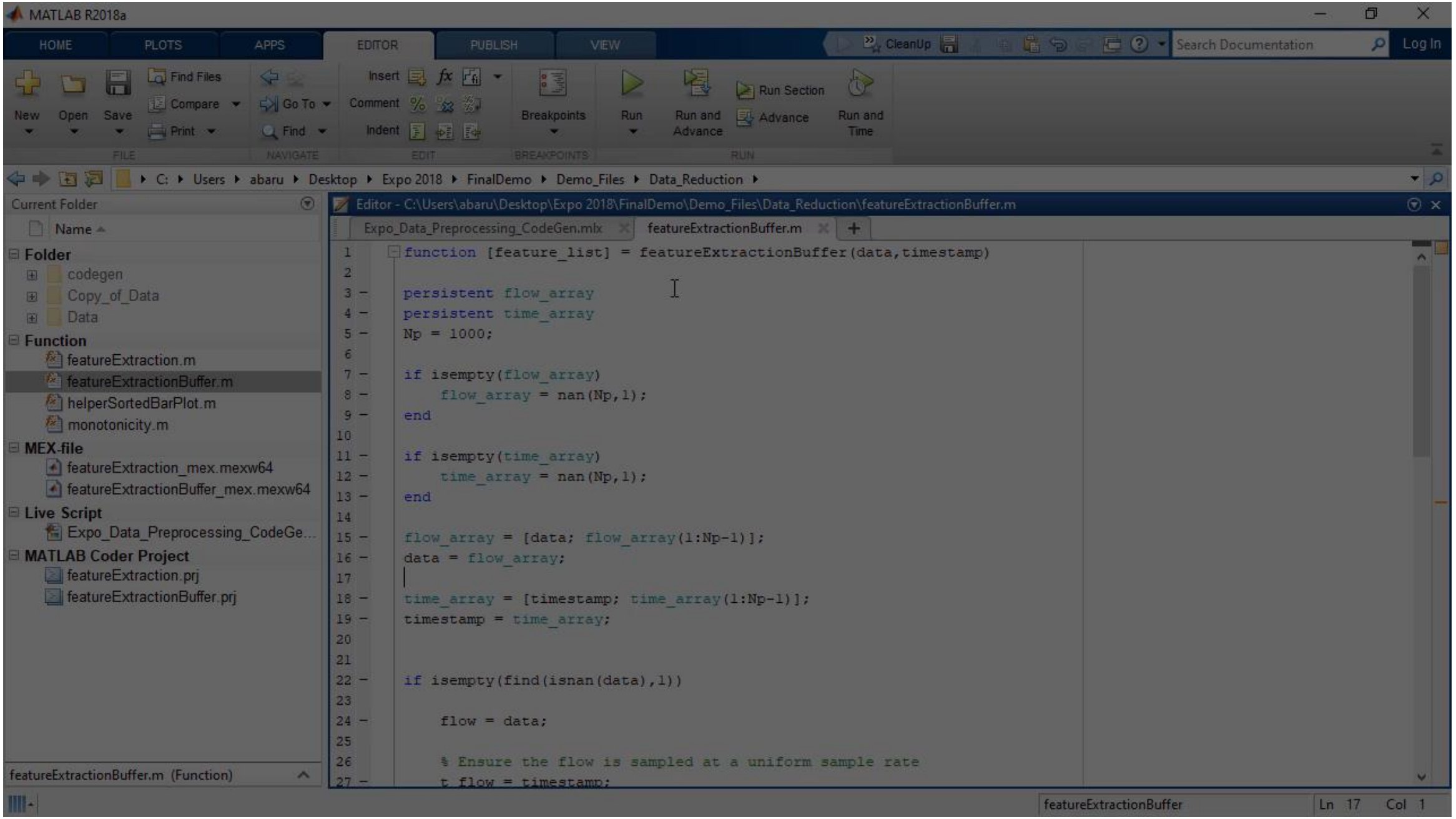
Predictive Maintenance using MATLAB: Pattern Matching for Time Series Data 28

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

Value of the Data **v/s** How Old is the Data




MATLAB R2018a
HOME
PLOTS
APPS
EDITOR
PUBLISH
VIEW
CleanUp
Search Documentation
Log In
New
Open
Save
Find Files
Compare
Print
Go To
Find
Insert
Comment
Indent
Breakpoints
Run
Run and Advance
Run Section
Advance
Run and Time
FILE
NAVIGATE
EDIT
BREAKPOINTS
RUN
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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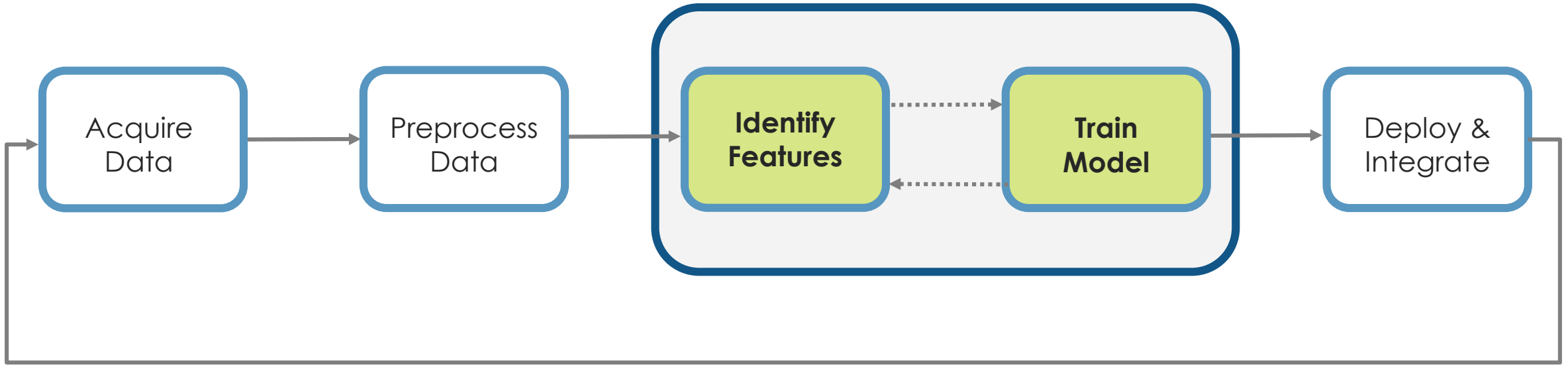
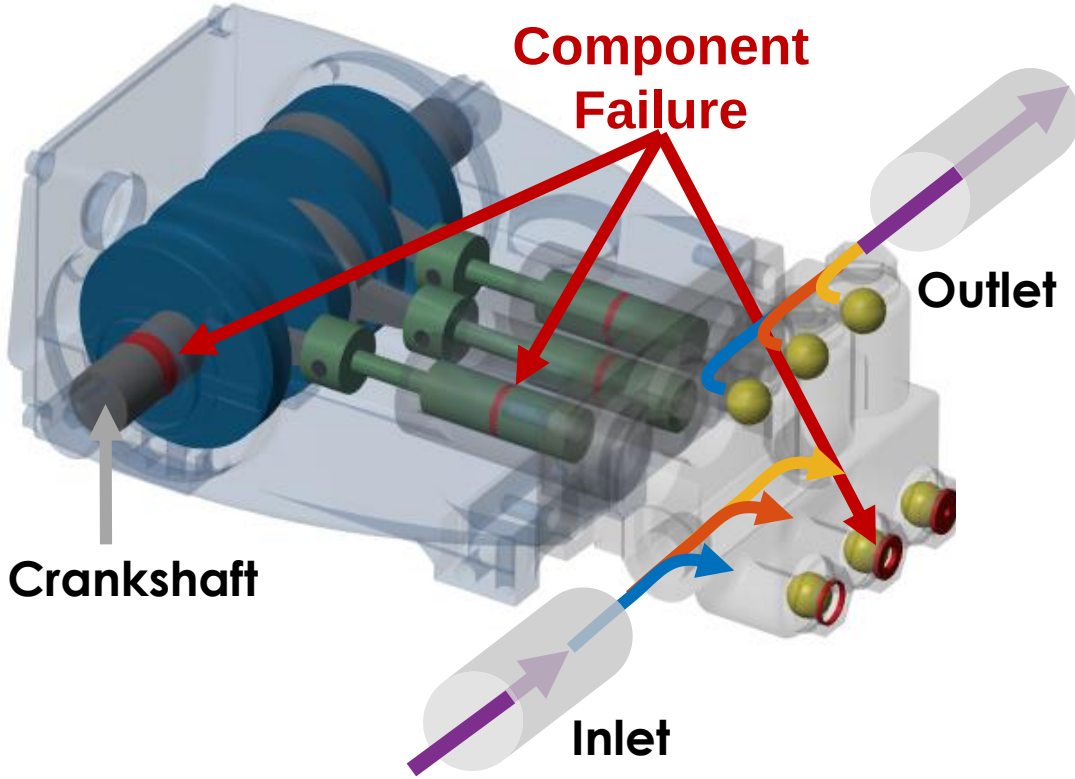


Fault Classification Algorithms Allow You to Identify the Root Cause of Anomalous Behavior

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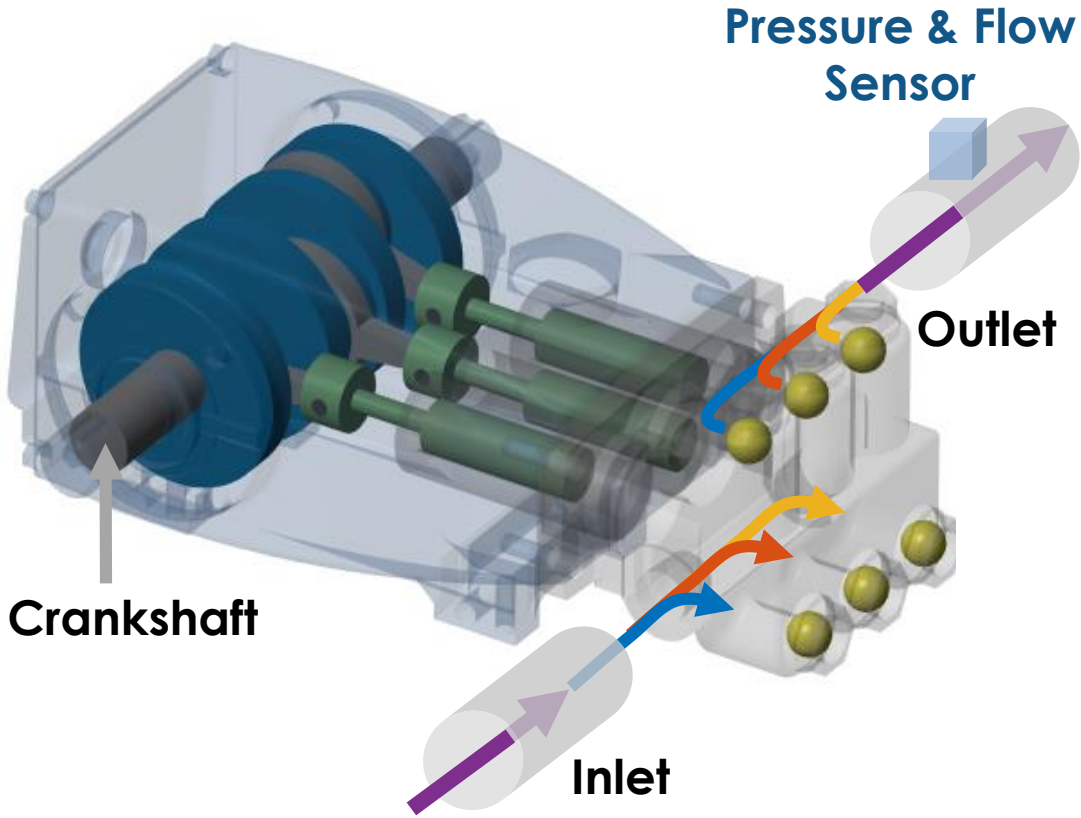
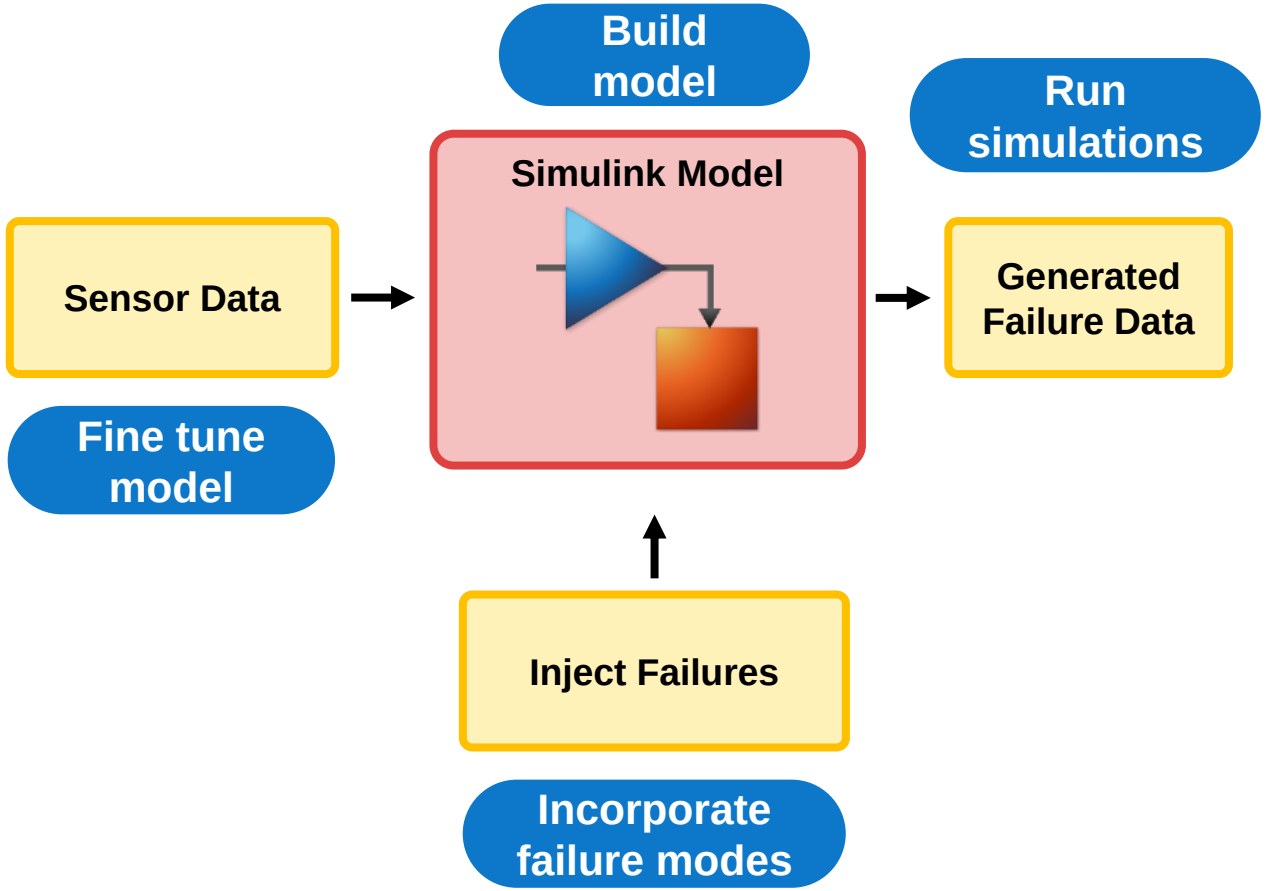
  - Bearing degradation
- Identify fault present in system using **only** pressure and flow sensor data



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



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Open Session | Save Session | Import Data | Signal Trace | Power Spectrum | Order Spectrum | Histogram | Select data to plot | Computation Options | Filtering & Averaging | Residue Generation | Spectral Estimation | Time-Domain Features | Spectral Features | Rank Features | Export

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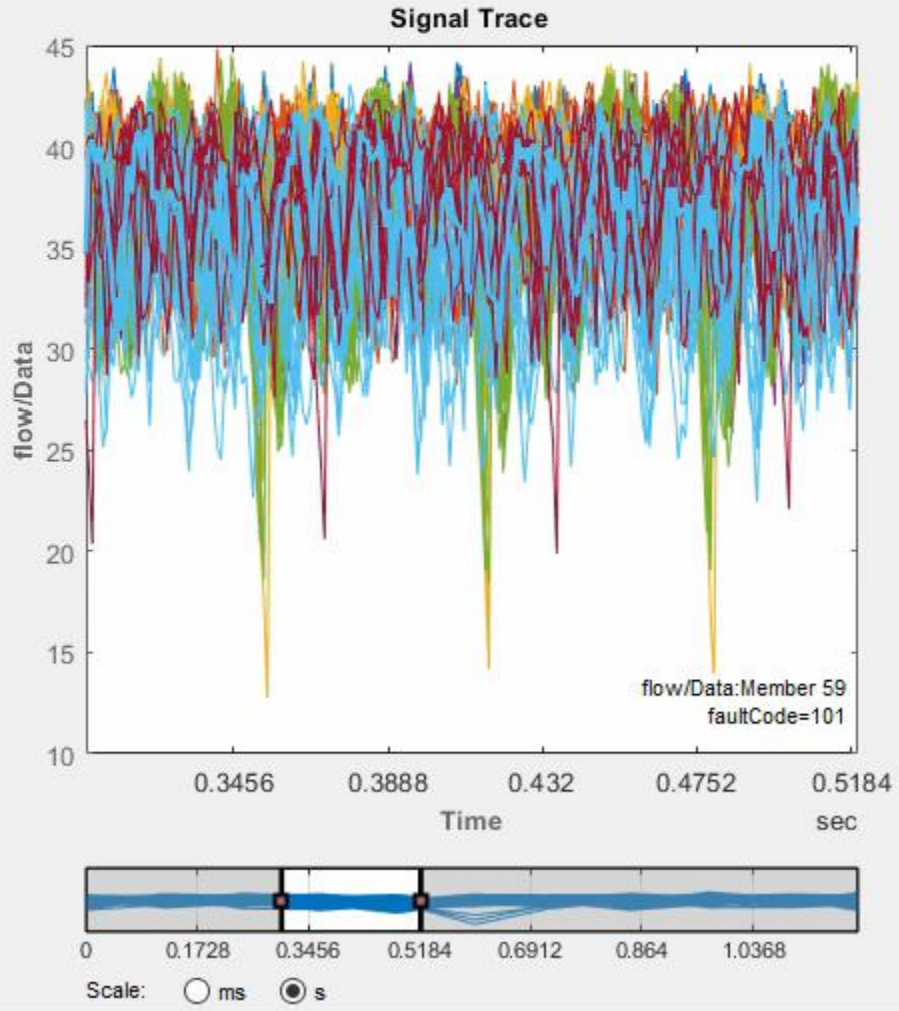
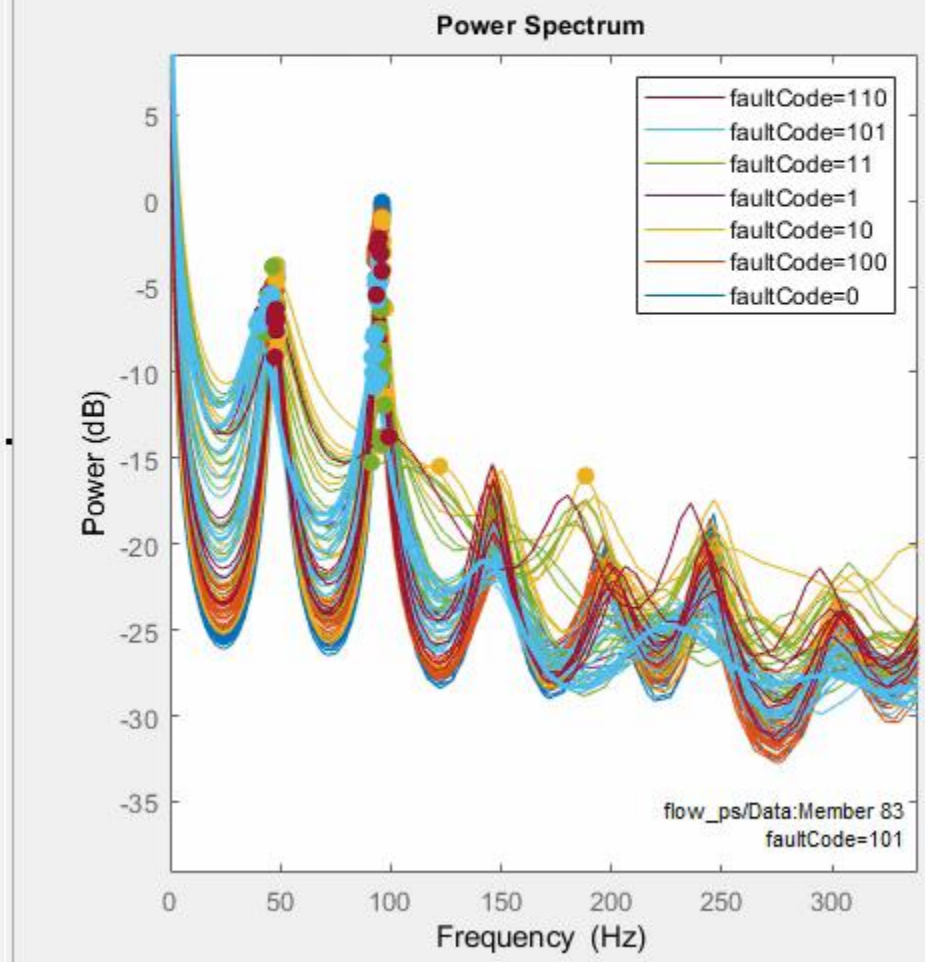
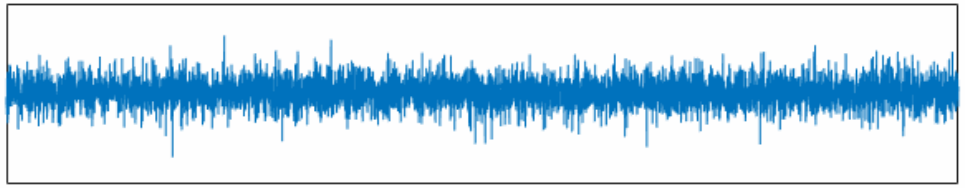


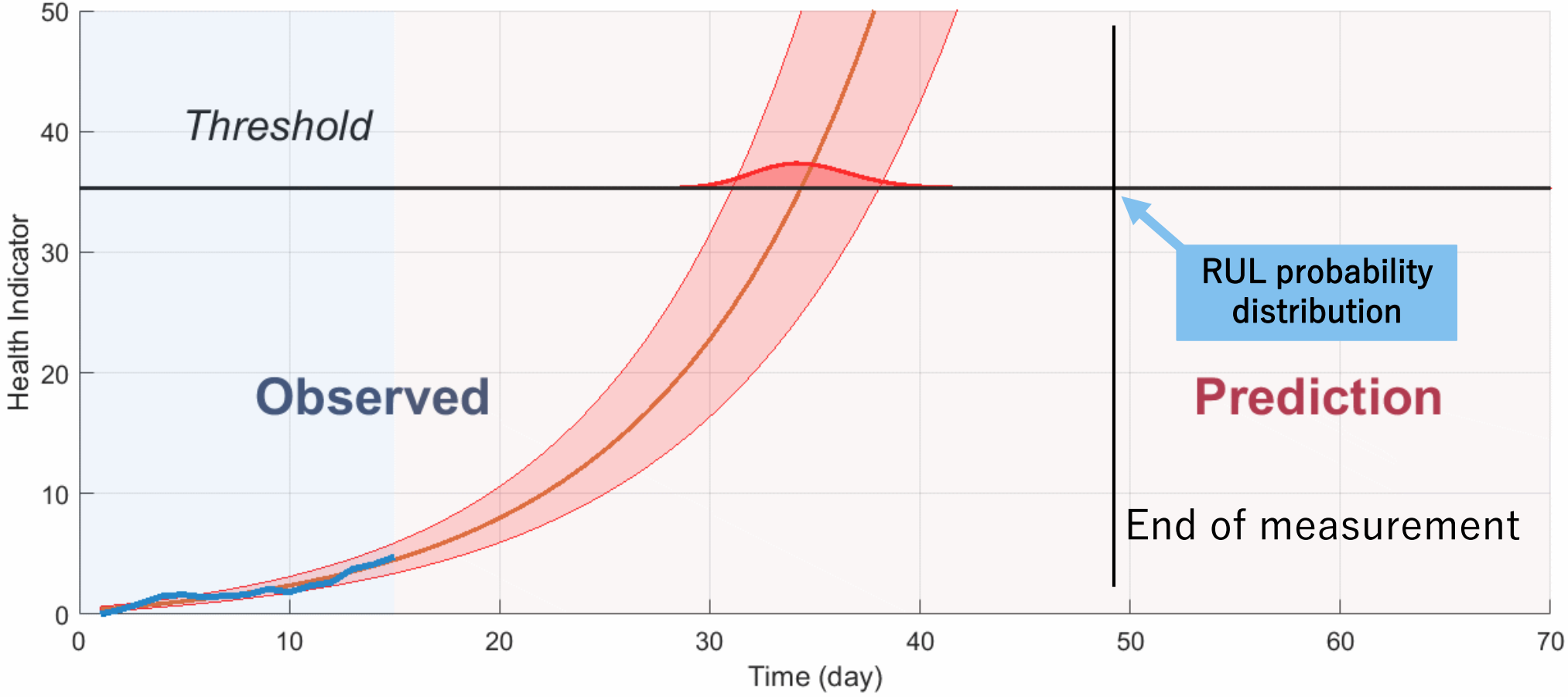
Power Spectrum: flow_ps/Data



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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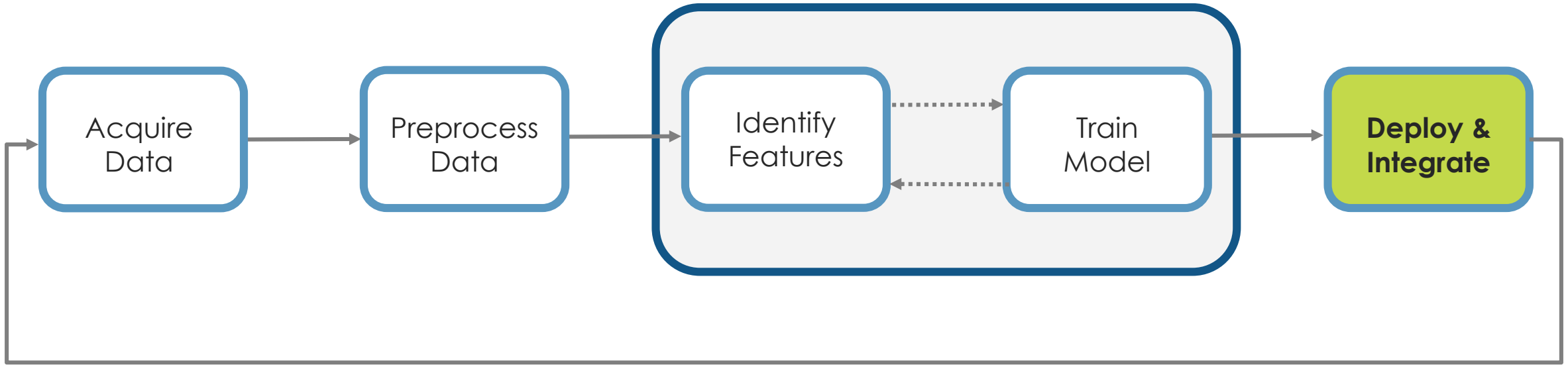
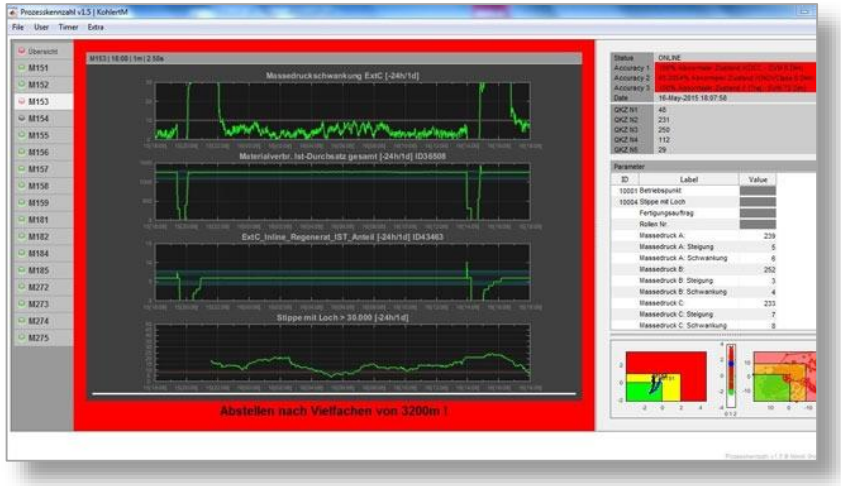
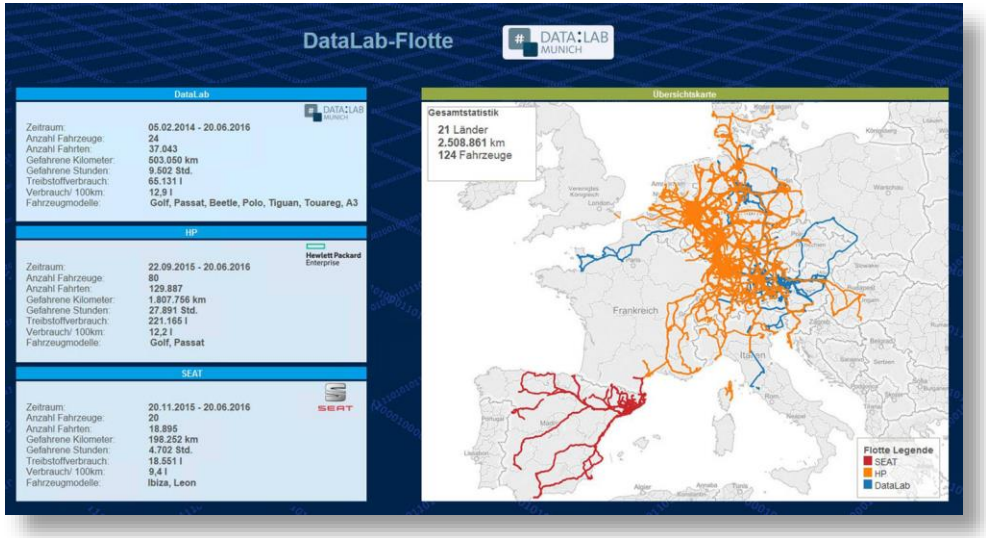


Challenges: Delivering results to your end users

- 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

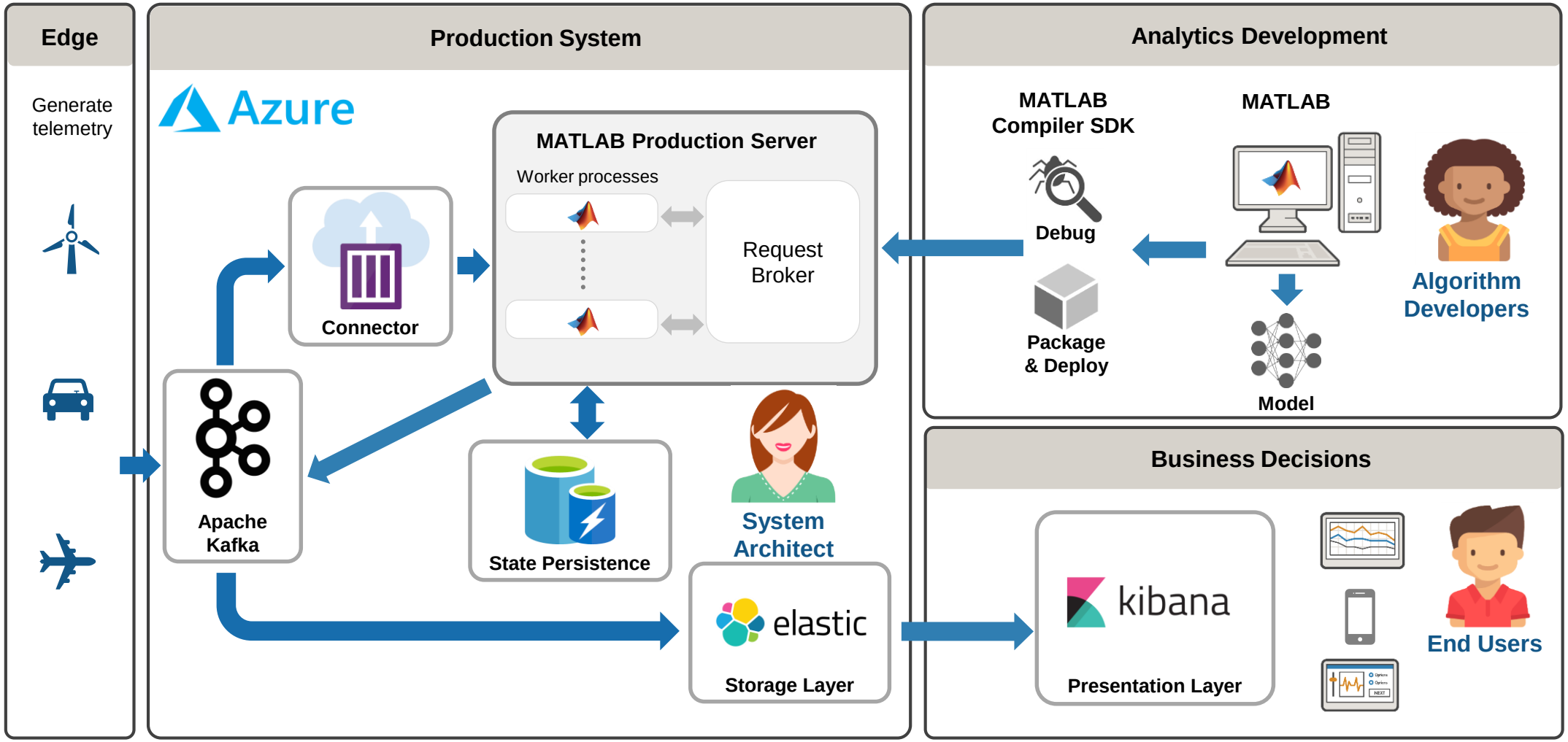


Dashboards



Fleet & Inventory Analysis

Predictive Maintenance Architecture on Azure



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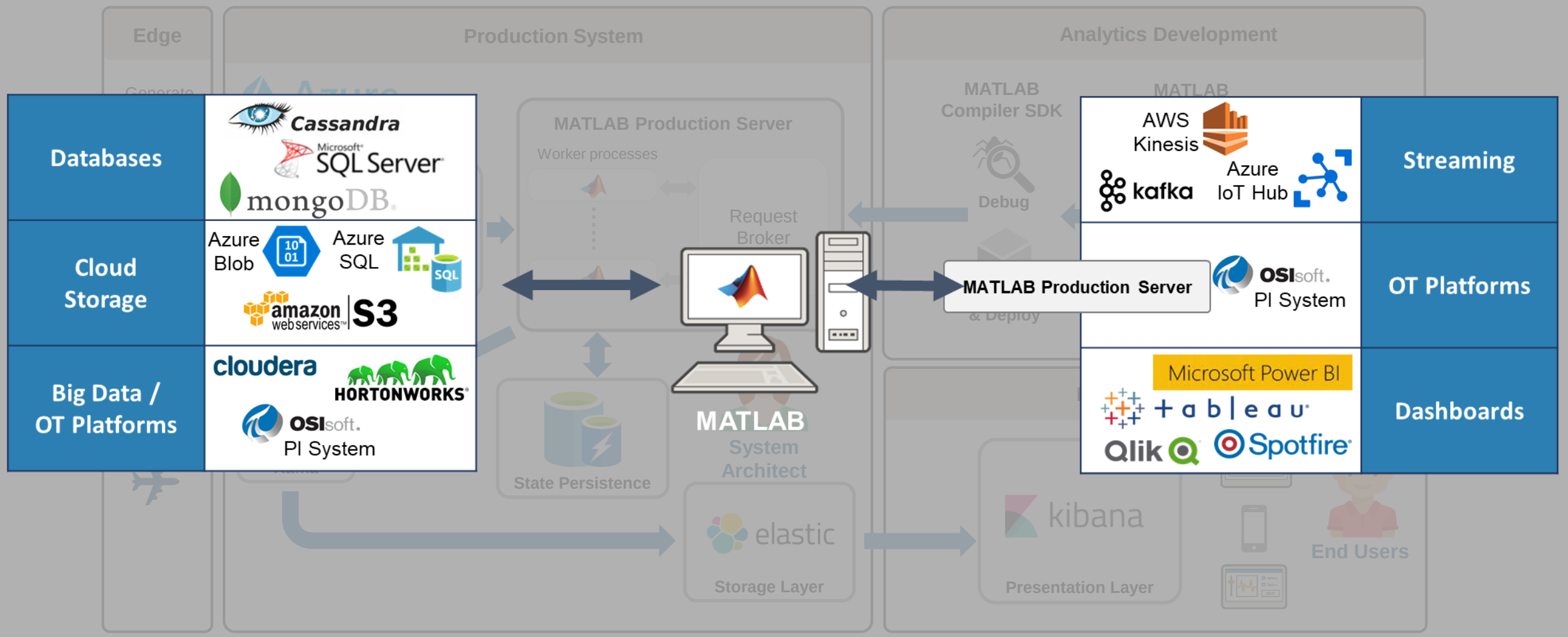

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MathWorks can help you get started **TODAY**

- Documentation & Examples
- Workshops
- Training
- Consulting
- … Booth !