MATLAB EXPO 2019

Predictive Maintenance with MATLAB – Master Class

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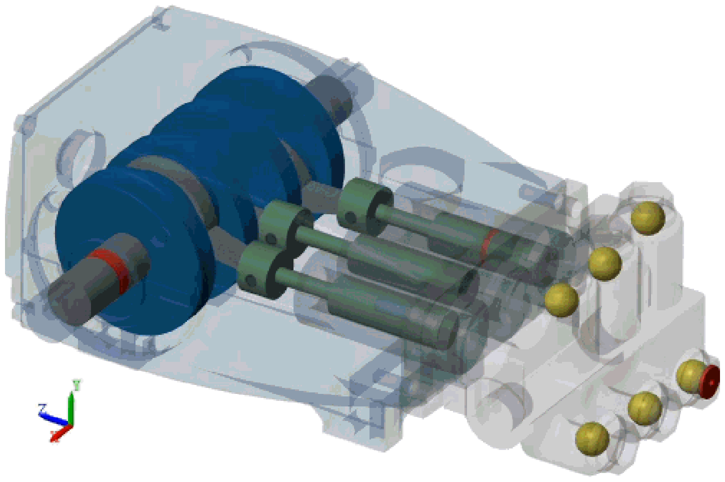
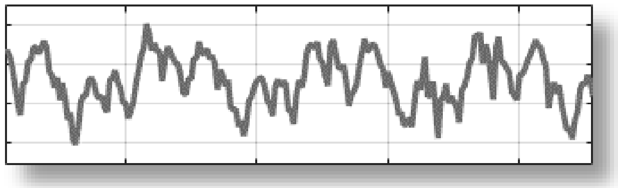
What is Predictive Maintenance?





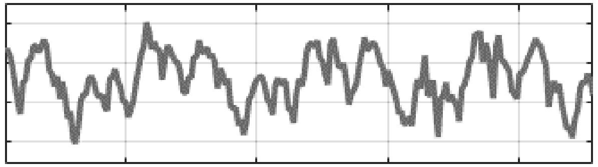
Translate

Turn off instant translation

English | Spanish | French | Pump - detected

English | Russian | Greek

Translate



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I need help.

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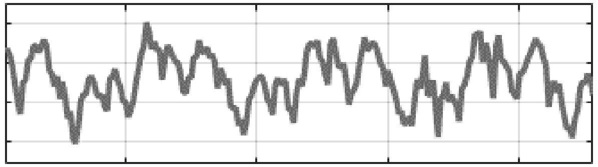

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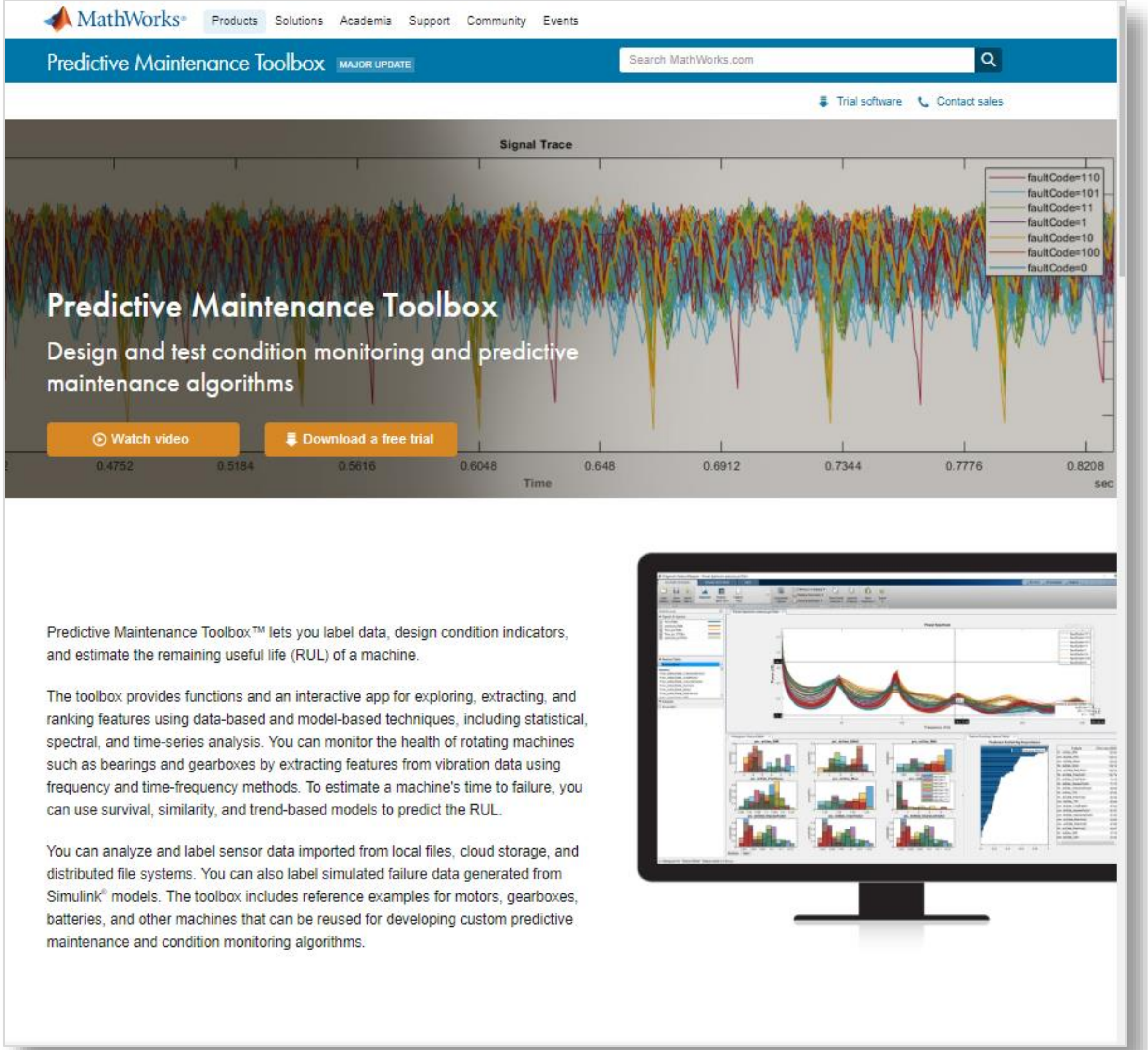
I need help. One of my cylinders is blocked. I will shut down your line in 15 hours

A Predictive Maintenance Algorithm Answers These Questions

Question	Task	Answer
Is my machine operating normally?	Anomaly Detection	I need help.
Why is my machine behaving abnormally?	Condition Monitoring	One of my cylinders is blocked.
How much longer can I operate my machine ?	Remaining Useful Life Estimation	I will shut down your line in 15 hours.

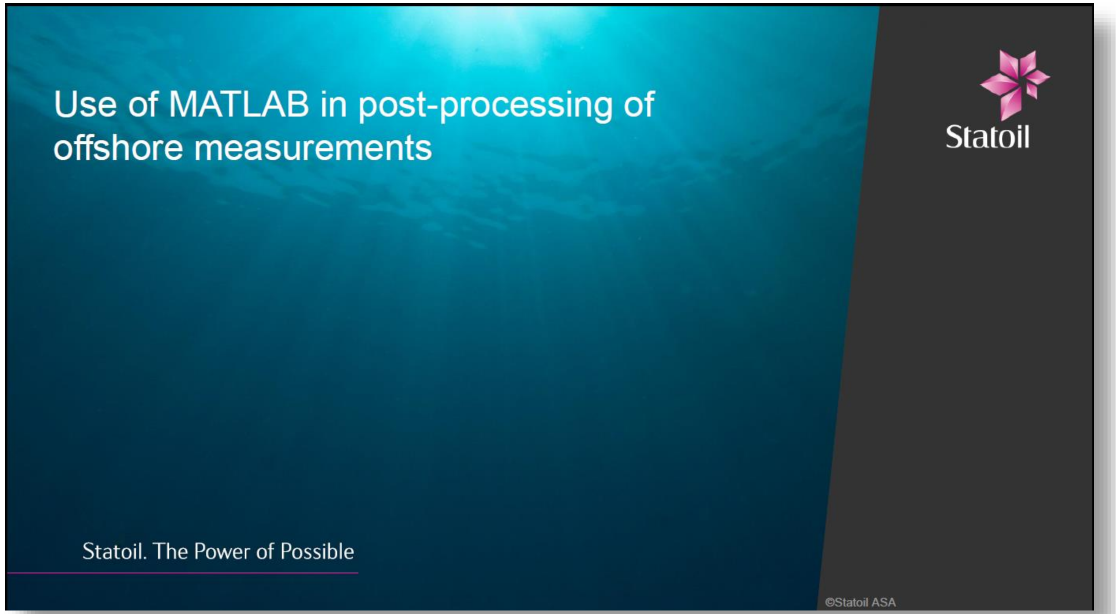
Predictive Maintenance Toolbox for Developing Algorithms

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?

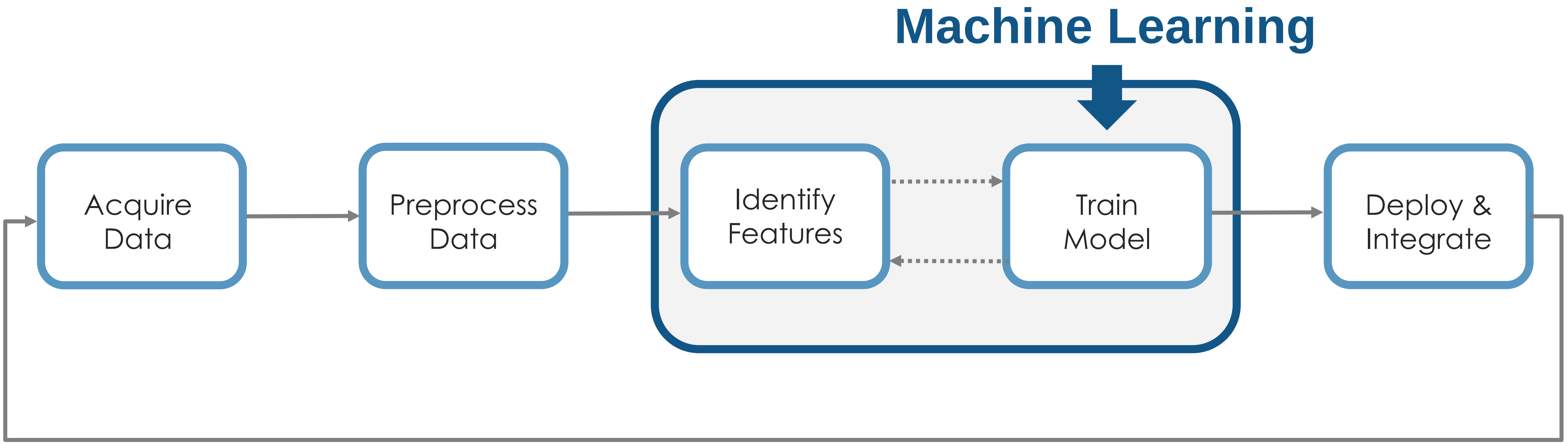
Link to user story



Link to user story

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 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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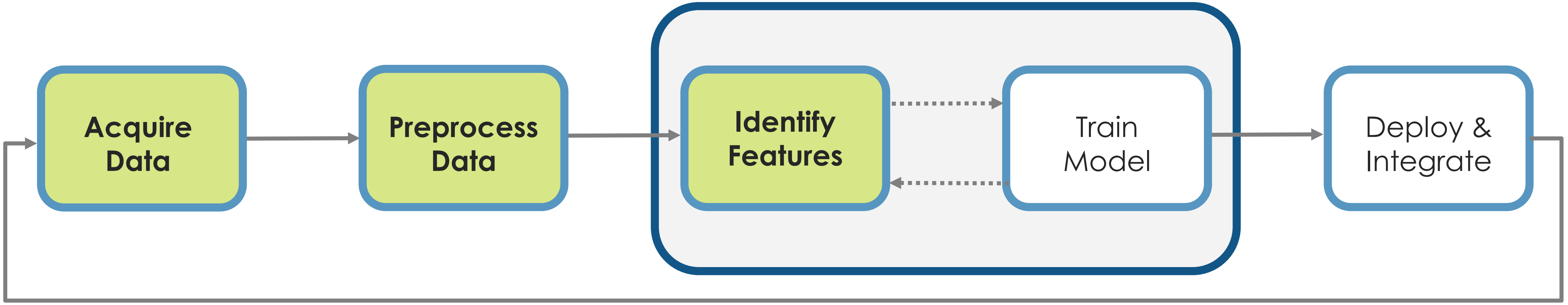
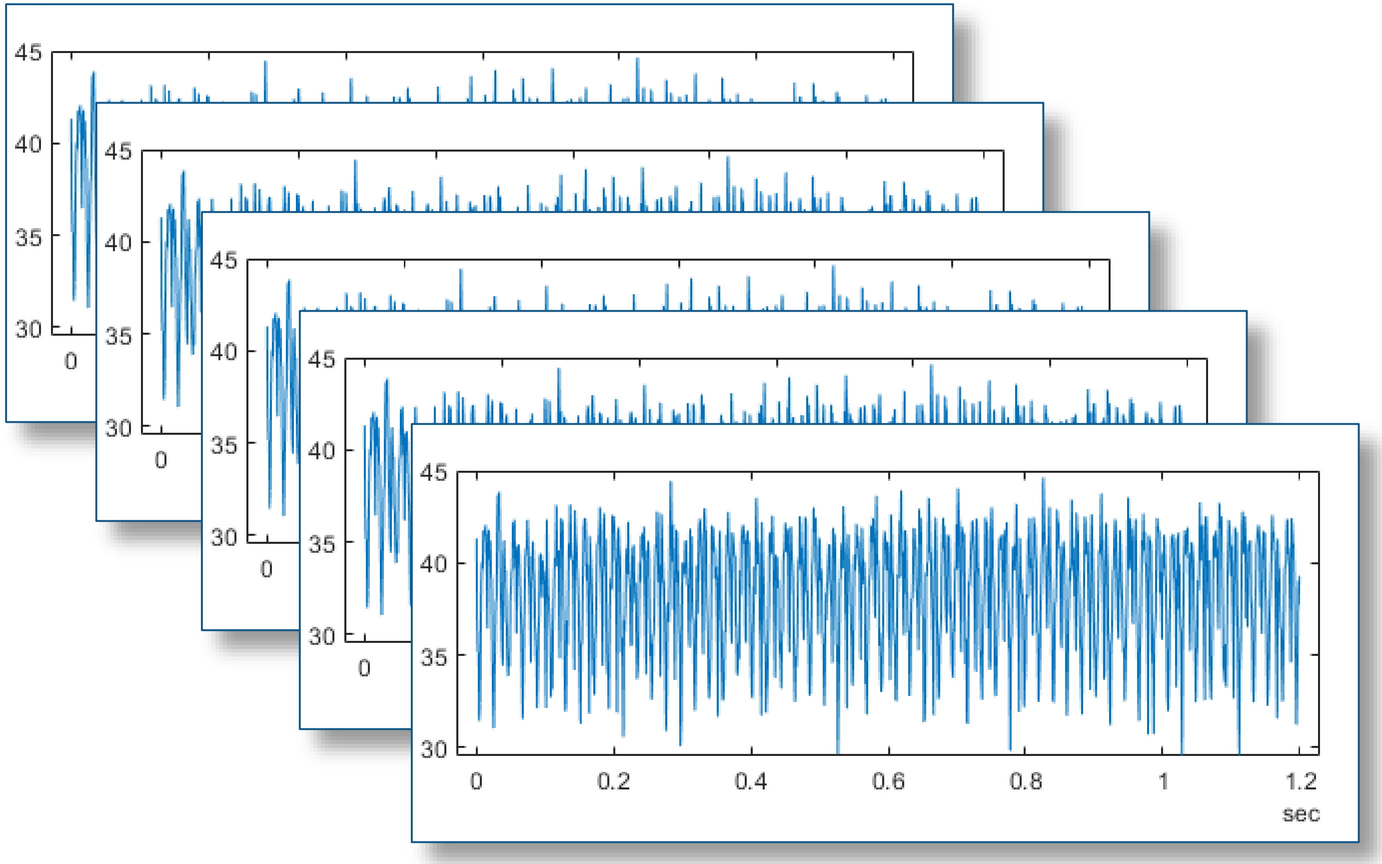


Challenges: How do you make sense of the ALL the data being collected?

- 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*



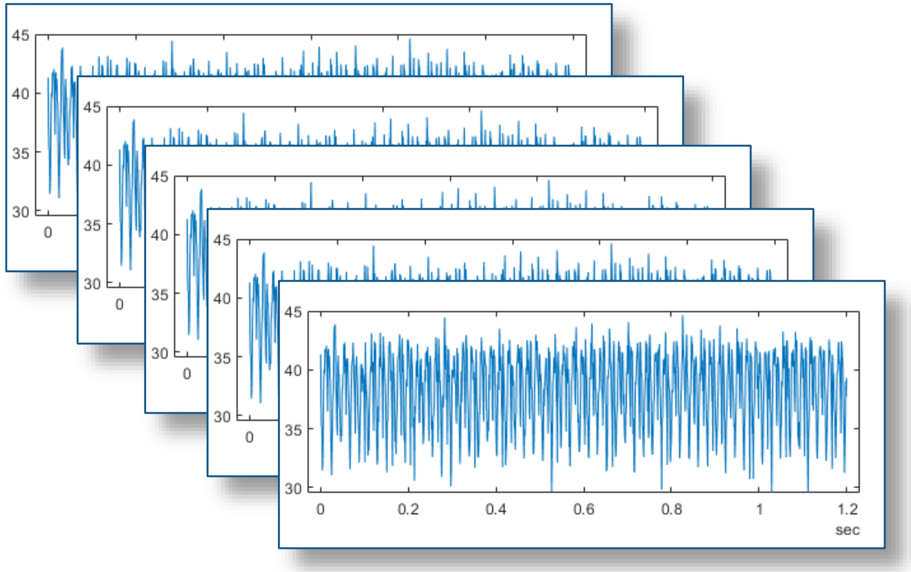
Solution: Feature Extraction

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 application, data, and hardware
  - Requires domain-knowledge

- How do I deal with streaming data?
  - Determine buffer size
  - Extract features over a moving buffer window



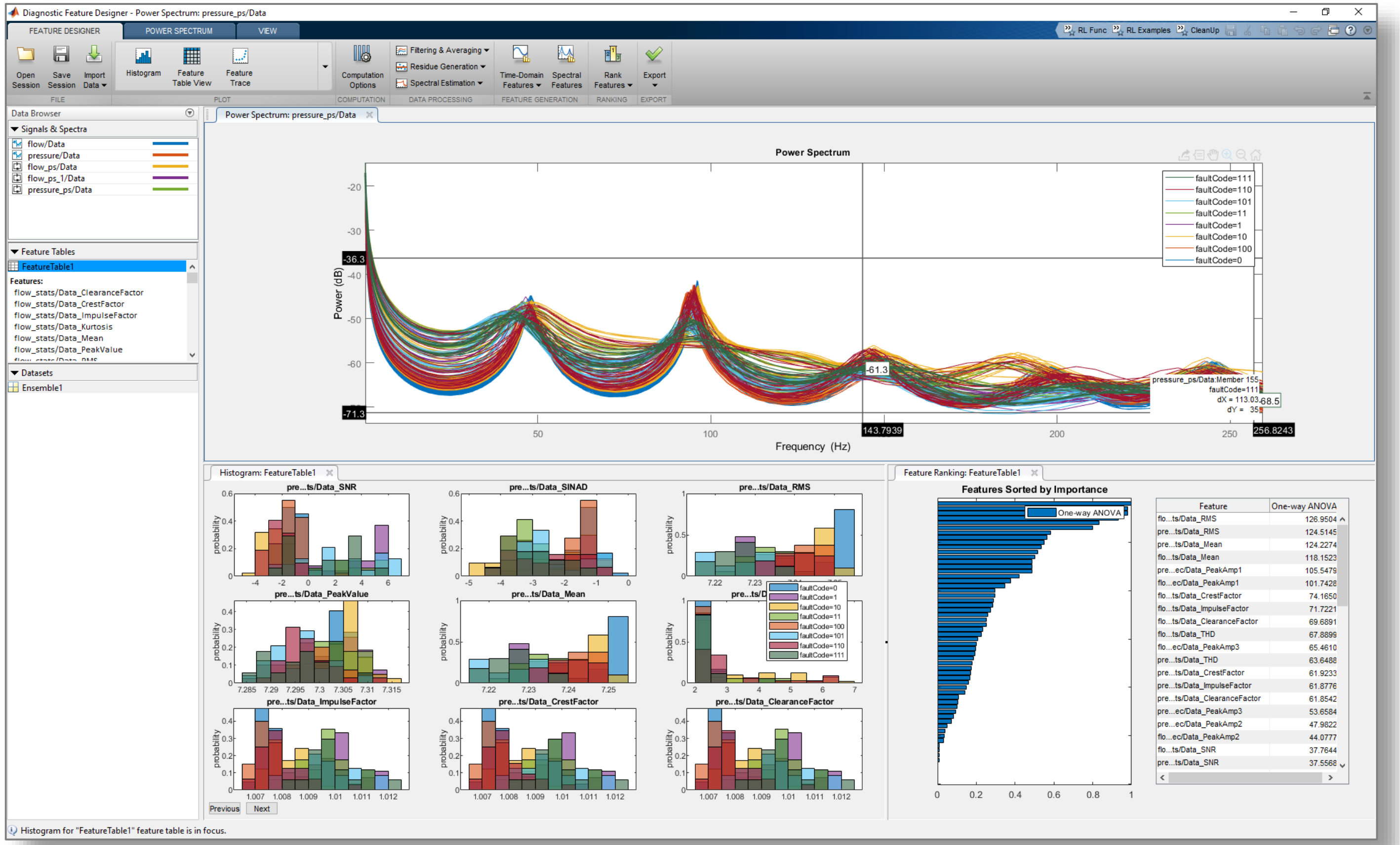
qMean	qVar	qSkewness	qKurtosis
38.4945	9.2306	-0.5728	2.4662

qPeak2P...	qCrest	qRMS	qMAD
15.2351	1.1553	38.6141	2.5562

Diagnostic Feature Designer App

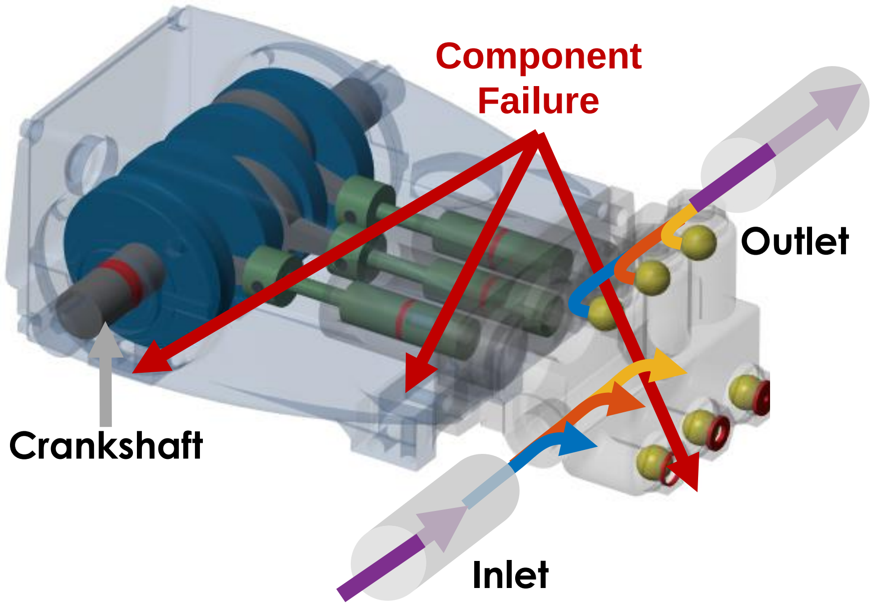
Predictive Maintenance Toolbox R2019a

- 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

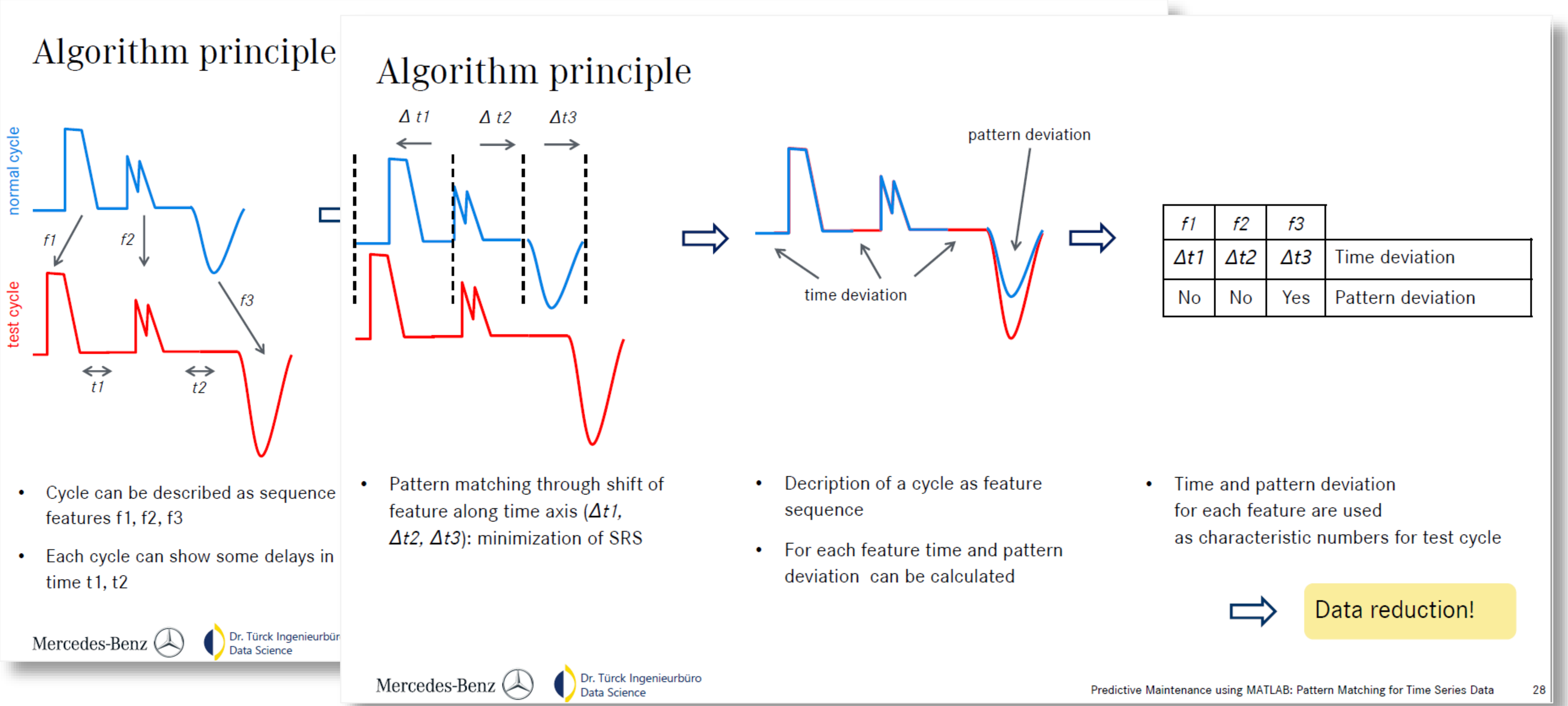


Demo: Extracting features from a signal

- Scenario: we want to monitor the condition of industrial pumps.
- Data: pressure/flow data collected from industrial pumps with different failures, 240 logs in total
- Goal: transform the sensor data into **descriptive features** that help us distinguish better the different failures and **reduce the amount of data**

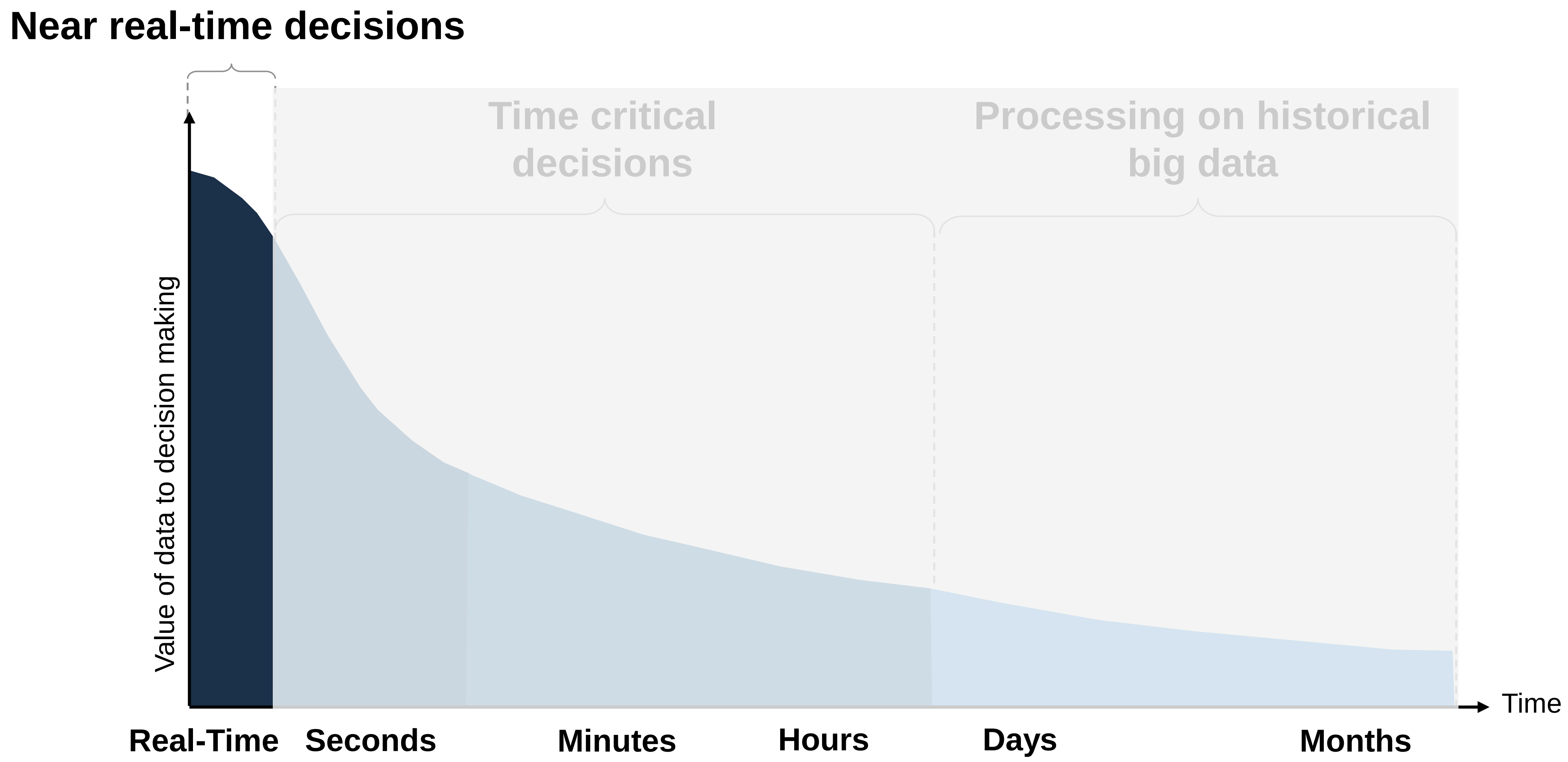


Daimler are Using MATLAB Today for Anomaly Detection



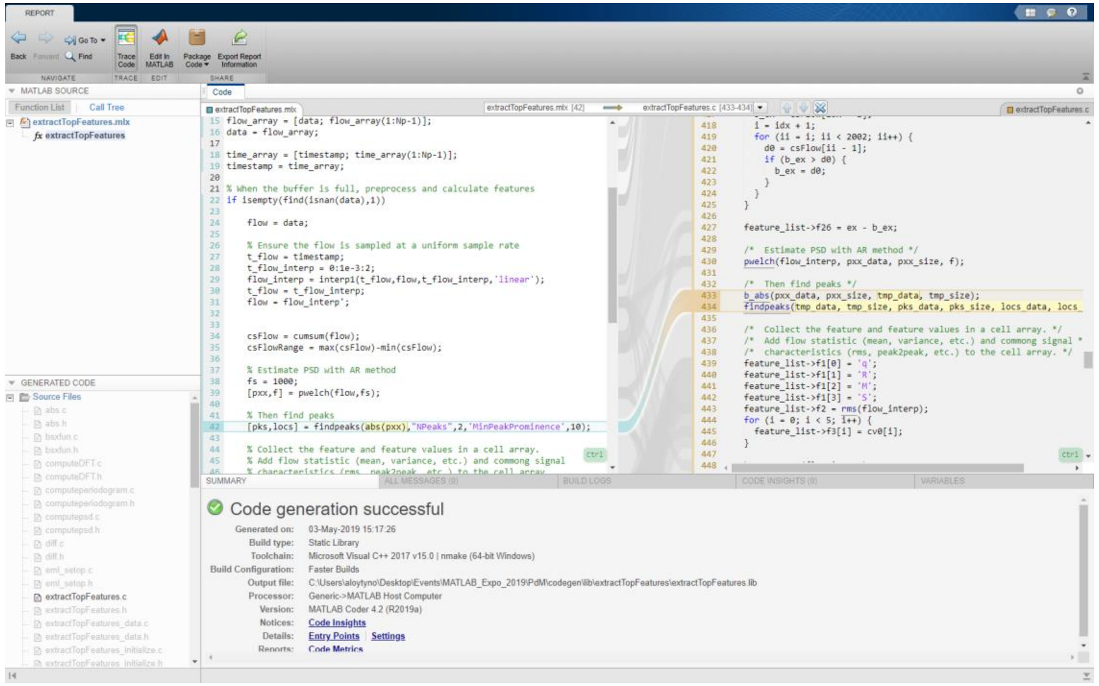
Data reduction of time series by a factor of **250x without a significant loss of information**

When is Your Data Most Valuable?



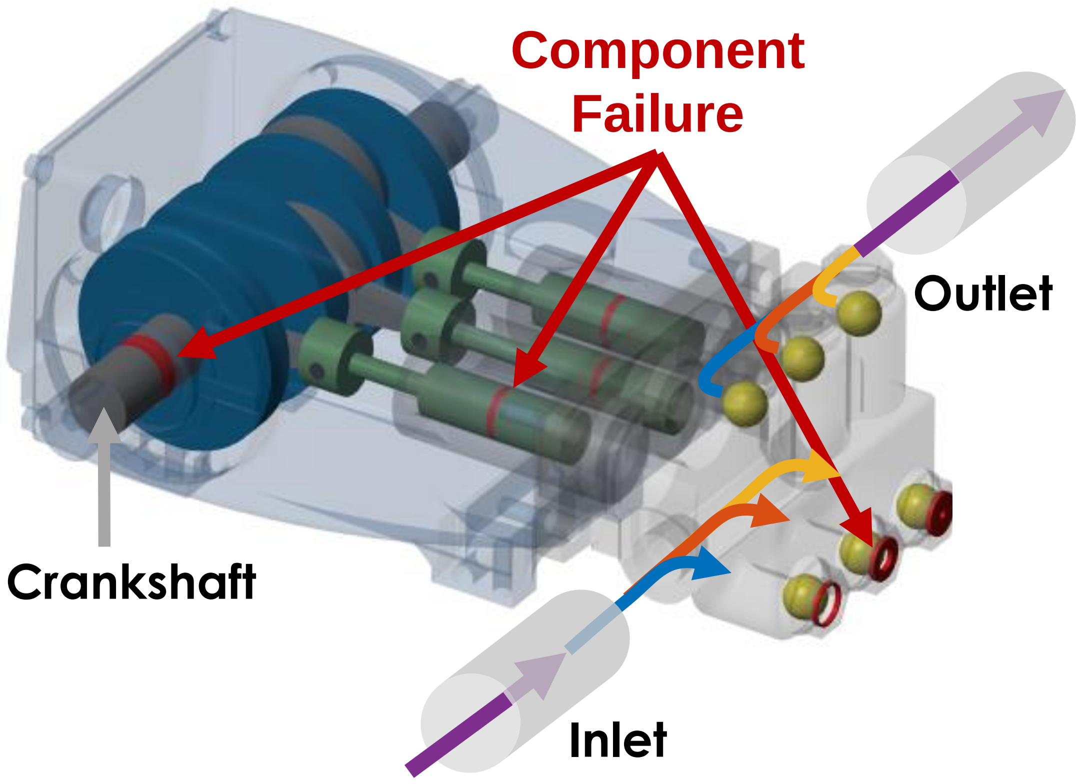
Demo: generating code for embedded systems

- Scenario: We have designed a feature extraction algorithm in MATLAB
- Goal: To implement the algorithm on an embedded system, for near-real-time processing, and to reduce the amount of data to be sent to cloud



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

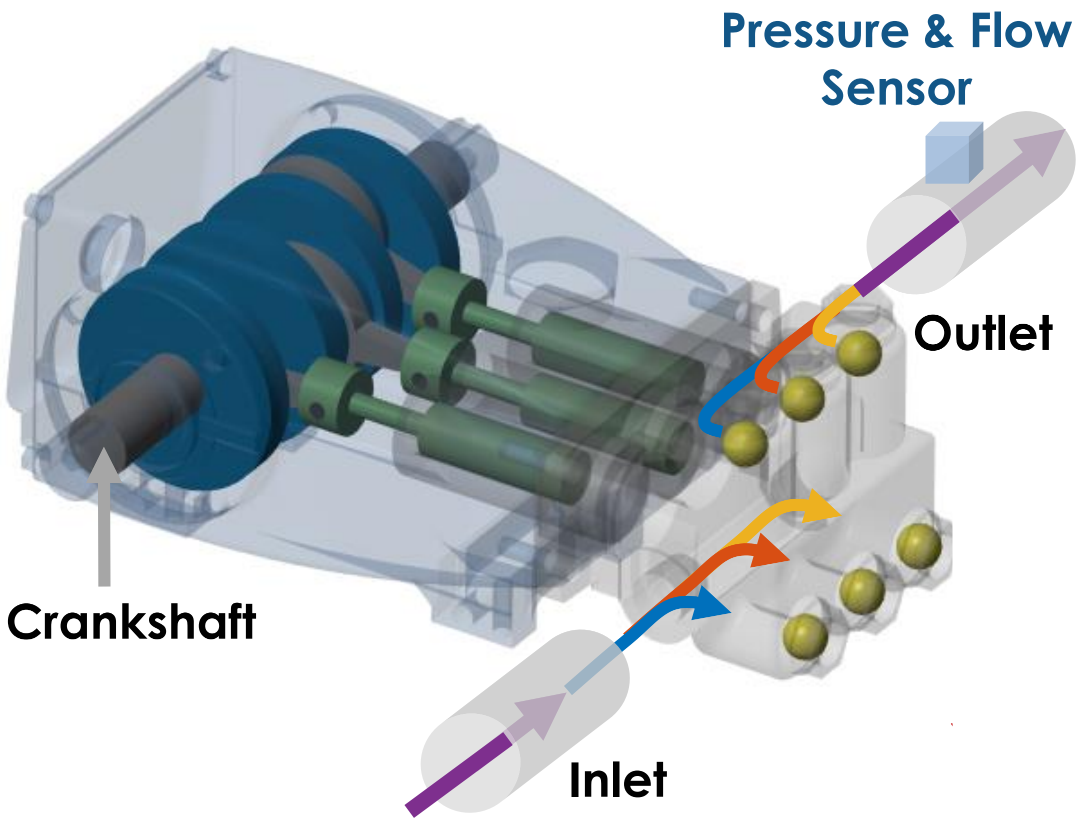
- Condition monitoring to detect:
  - Seal leak
  - Inlet blockage
  - Bearing degradation



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

- Condition monitoring to detect:
  - Seal leak
  - Inlet blockage
  - Bearing degradation

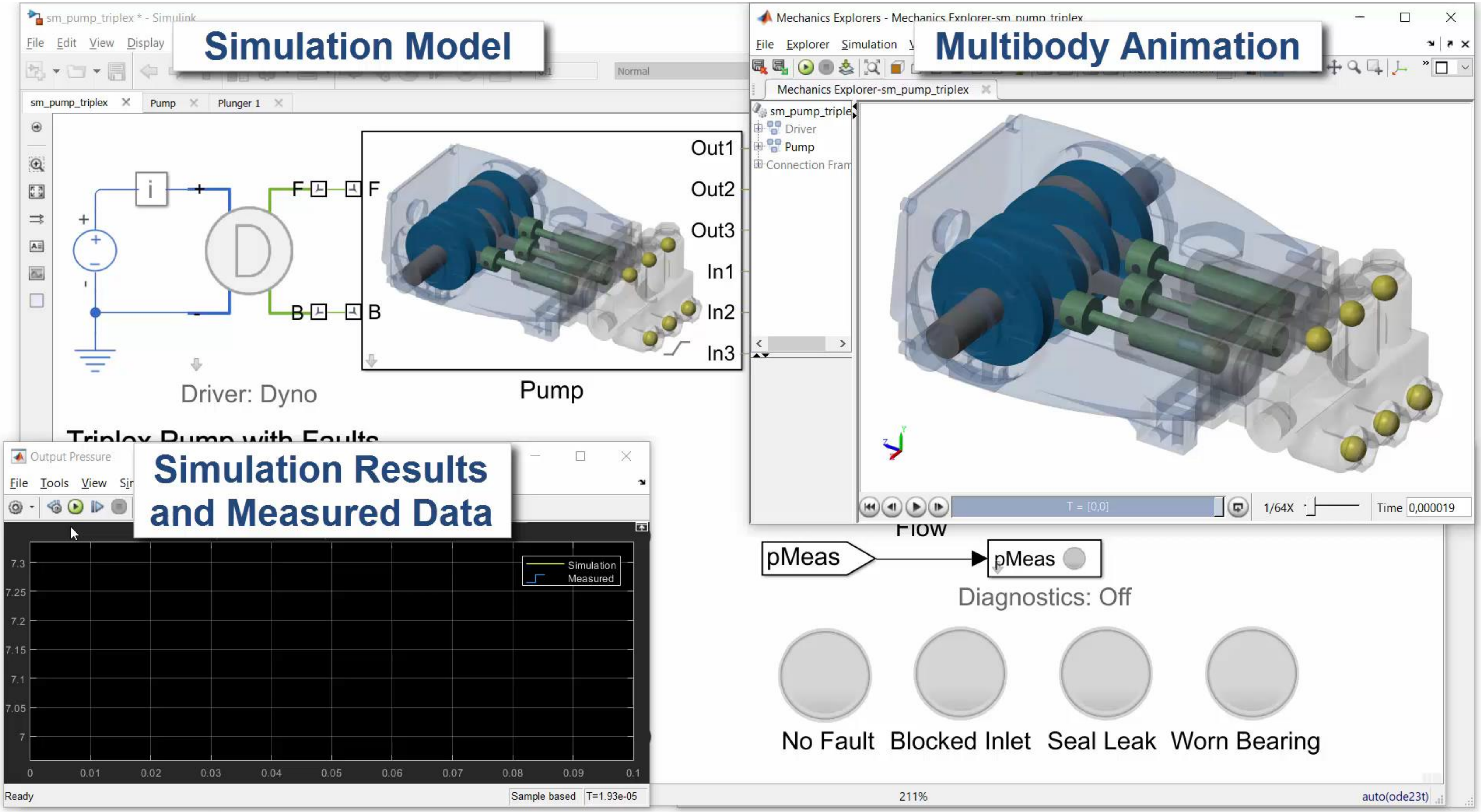
- Identify fault present in system using **only** pressure and flow sensor data



Challenges: not enough data (or the right kind of data)!

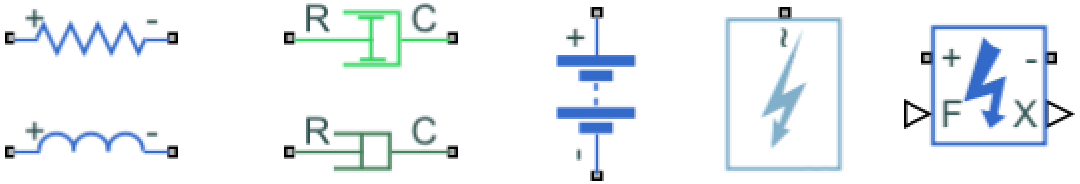
- You may have not experienced all potential failures in the equipment, or it's too costly to run real pumps into failure

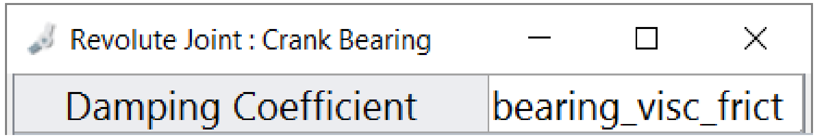
- Solution: Build a digital twin of the physical machine in Simulink/Simscape, and model the failures
  – **Simscape** has blocks to model and simulate multi-domain physical systems (electrical/hydraulical/mechanical)

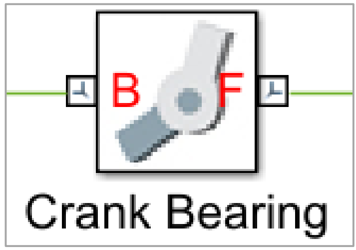

Simulation Model
Multibody Animation
Simulation Results and Measured Data
sm_pump_triplex * - Simulink
Mechanics Explorers - Mechanics Explorer-sm_pump_triplex
Driver: Dyno
Pump
Out1
Out2
Out3
In1
In2
In3
Output Pressure
Simulation
Measured
pMeas
Diagnostics: Off
No Fault
Blocked Inlet
Seal Leak
Worn Bearing

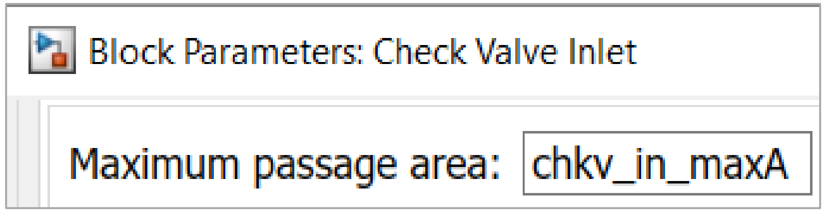
Model Component Failure

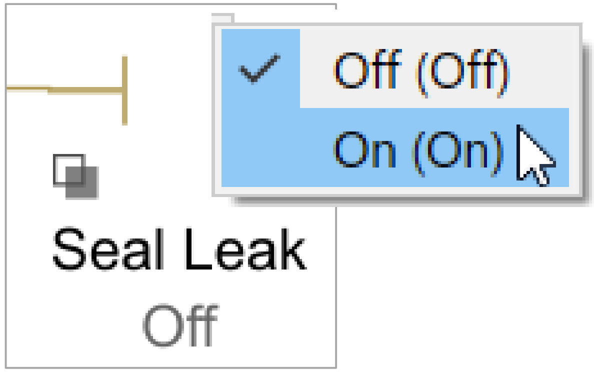
- Generic faults in many components
  - Short circuit, open circuit, friction, fade, etc.
  - Trigger based on time or conditions
- Adjust parameter values
  - Worn bearing adds friction
  - Blocked inlet has reduced passage area
- Adjust network
  - Seal leakage adds flow path
- Custom effects in Simulink
  - Broken winding applies no torque for 1/3 of every revolution

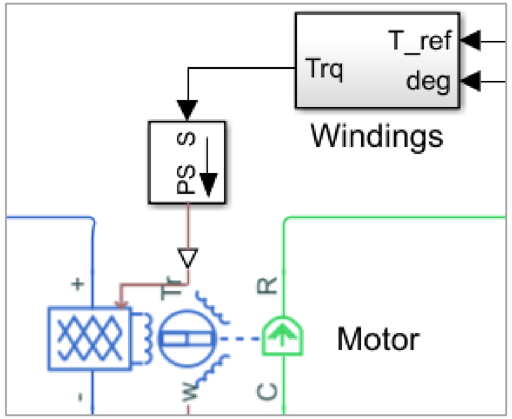






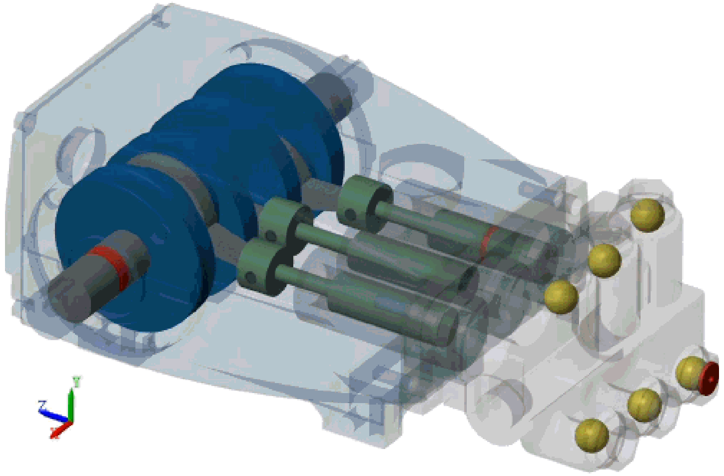


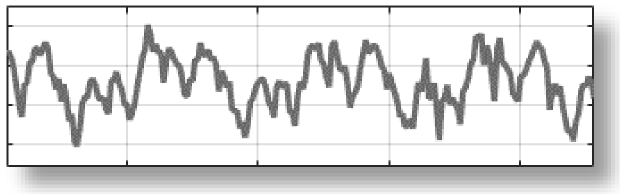




Demo: Generating failure data with a digital twin

- Scenario: We've already built and tuned our digital twin
- Goal: Generate synthetic failure data by running multiple simulations with varying levels of degradation/failure





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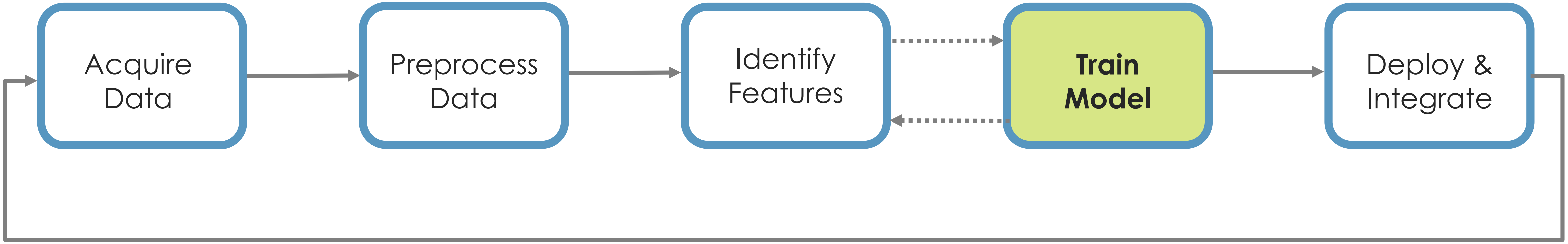
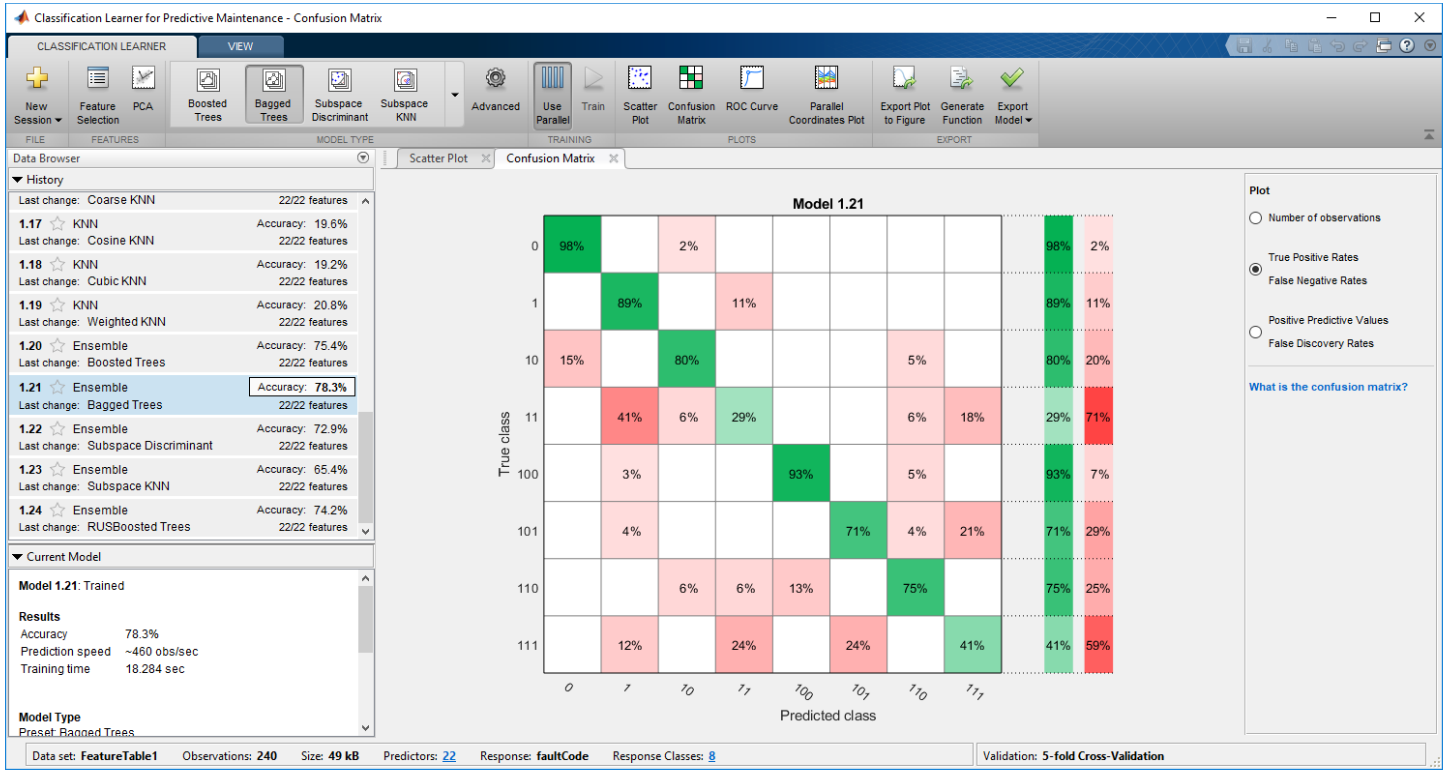
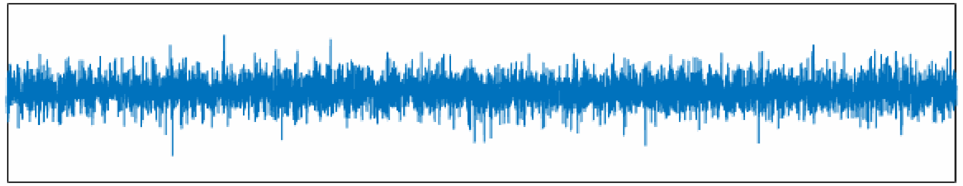


Demo: Create a Machine Learning Model for Condition Monitoring

- Scenario: We have simulated data from all the failures (blockage, leakage, friction) and all of the possible combinations of these failures
- Goal: Create a classifier to identify the fault

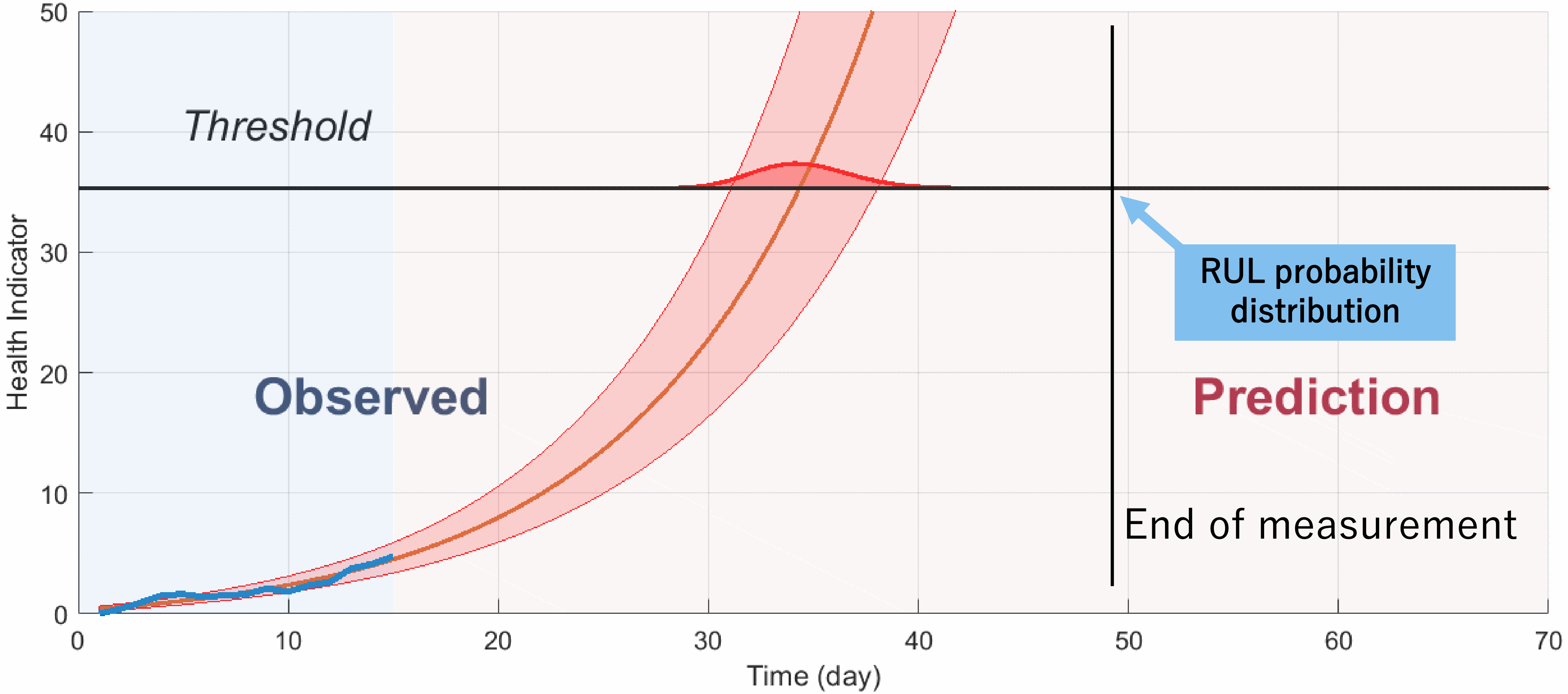


Estimate Remaining Useful (RUL) to Determine When You Should Perform Maintenance



RUL: 459 hours

(95%CI: 374-558 hours)



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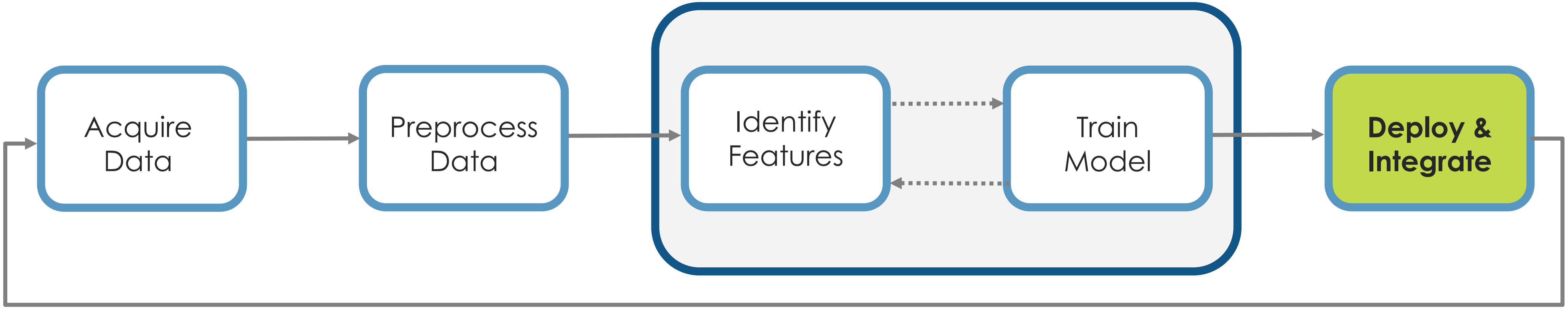


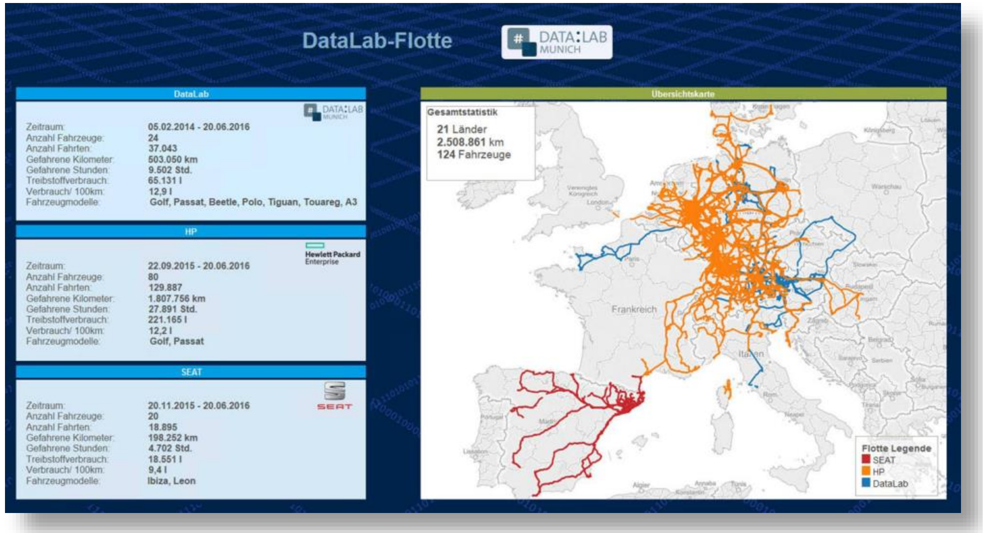
Challenges: Delivering results to your end users

- Maintenance needs simple, quick information
  - Hand held devices, Alarms

- Operations needs a birds-eye view
  - Integration with IT & OT systems

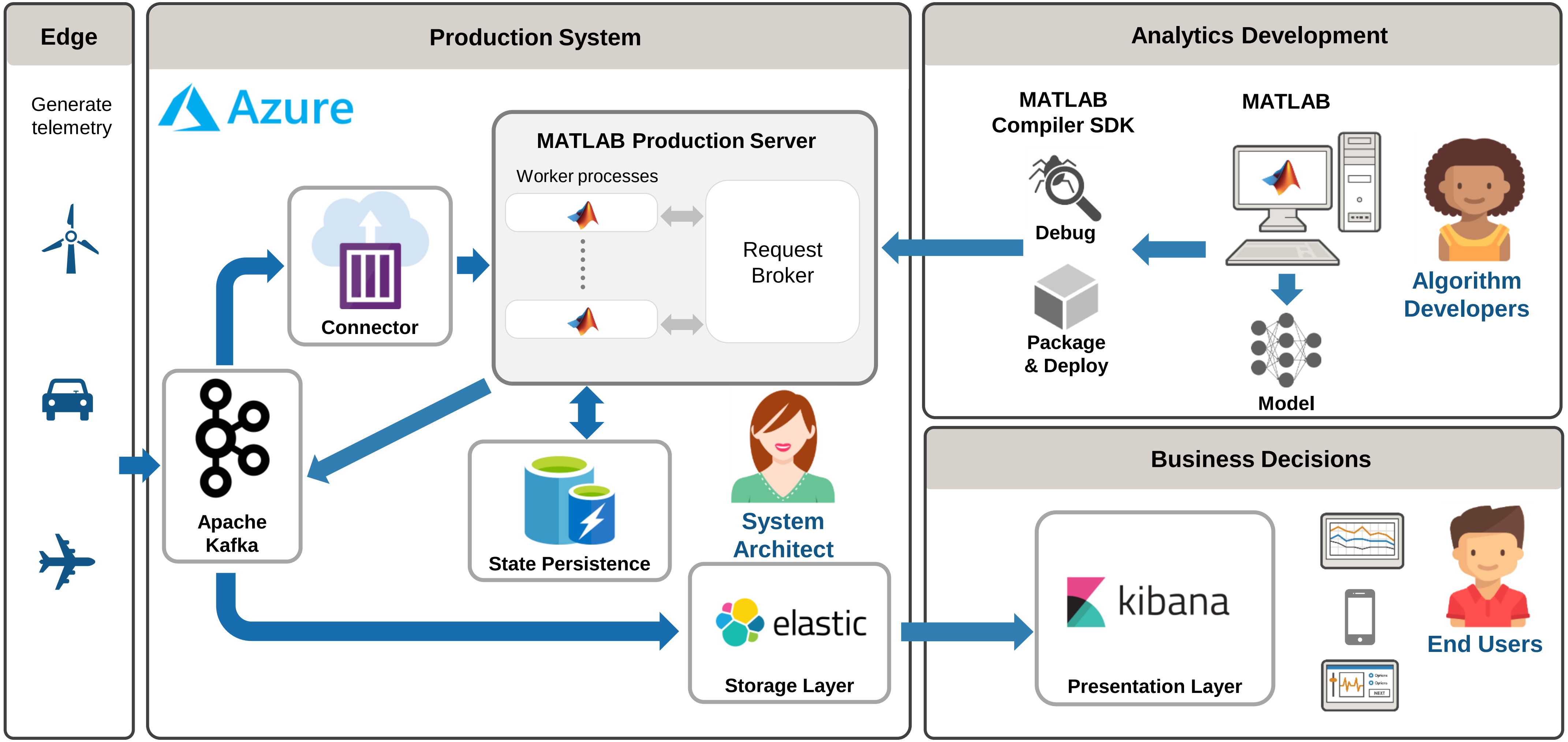
- Customers expect easy to digest information
  - Automated reports

Dashboards



Fleet & Inventory Analysis

Predictive Maintenance Architecture on Azure



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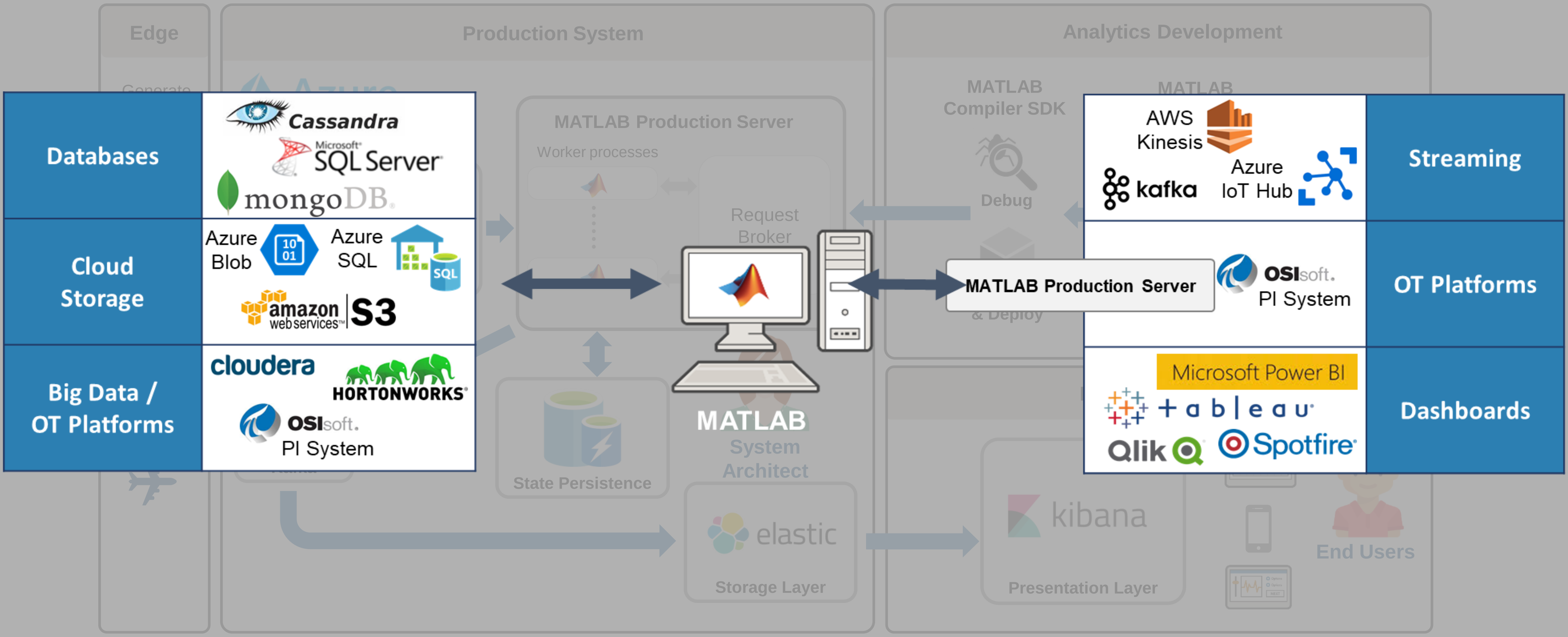
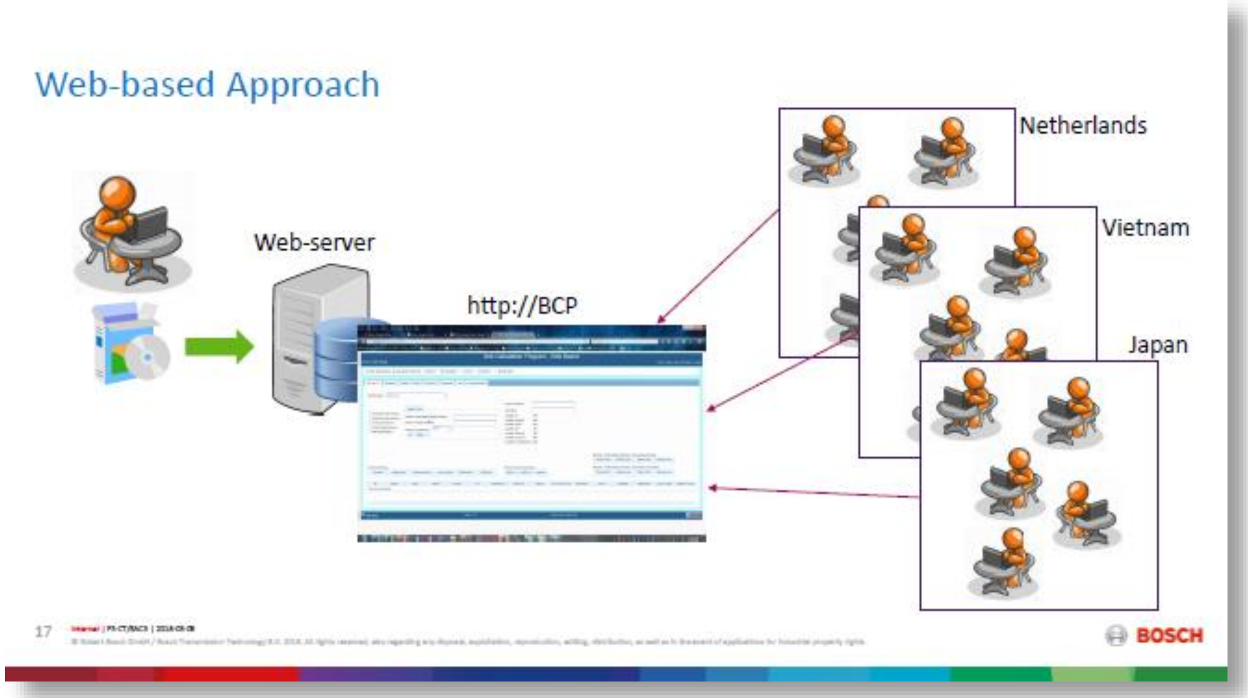
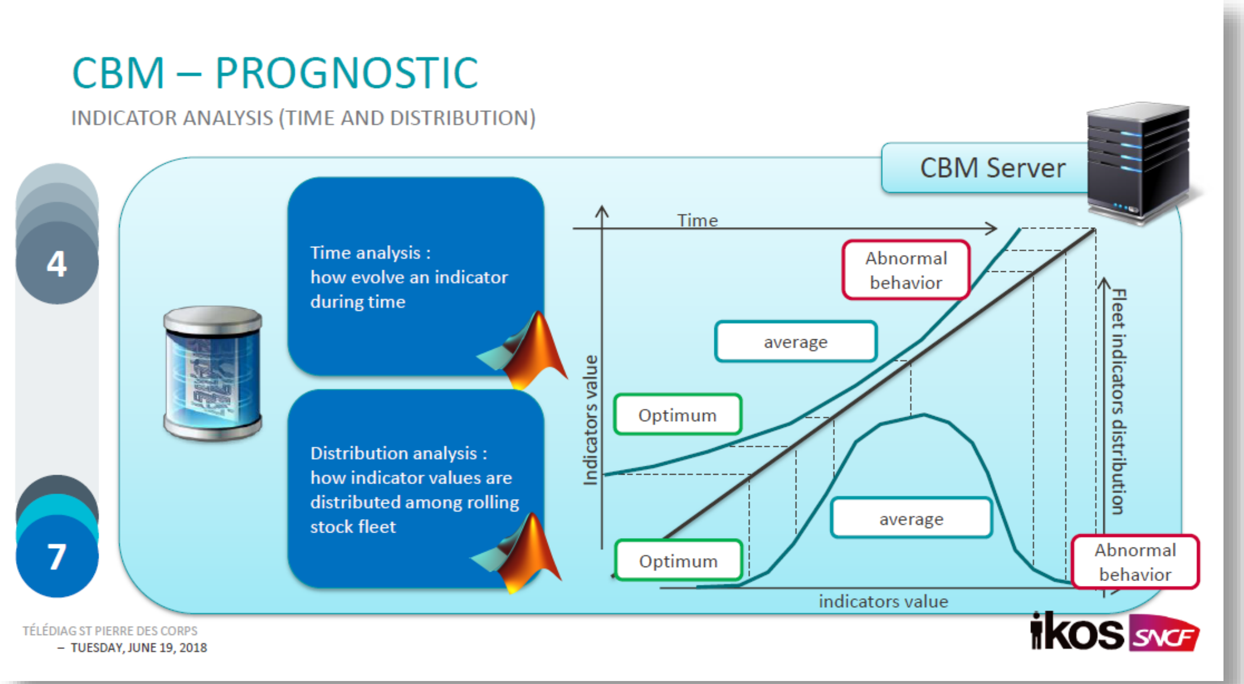


Bosch and SNCF Have Implemented Production Systems Running Today





Link to user story

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

"…[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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