

The background of the image is a blurred crowd of people, with a focus on a woman's hand in the foreground. The hand is positioned as if it is about to clap or is in the middle of a gesture. The hand is adorned with a silver bracelet featuring a large, ornate design. The overall lighting is soft and warm, creating a professional and inviting atmosphere.

MATLAB EXPO 2018  
KOREA

# MATLAB EXPO 2018

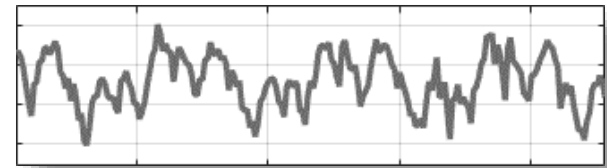
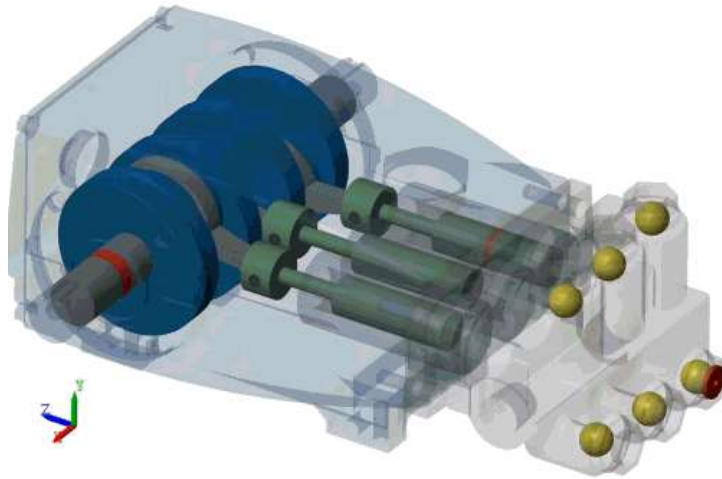
## 고장 진단 및 건전성 관리 기술

알고리즘 개발에서 사물인터넷 환경 구성까지

Senior Application Engineer  
엄준상 과장



# What is Predictive Maintenance?



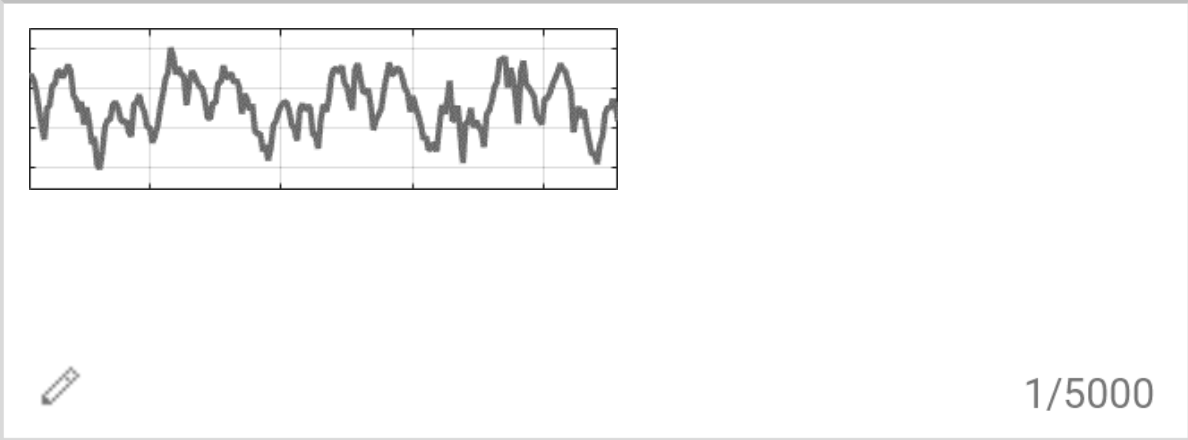


English Spanish French Pump - detected ▼



English Russian Greek ▼

Translate



I need help.

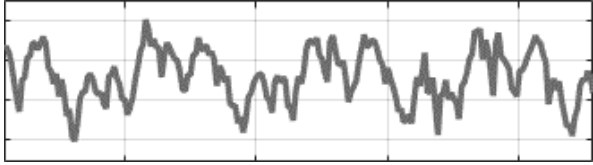


English Spanish French Pump - detected ▼



English Russian Greek ▼

Translate



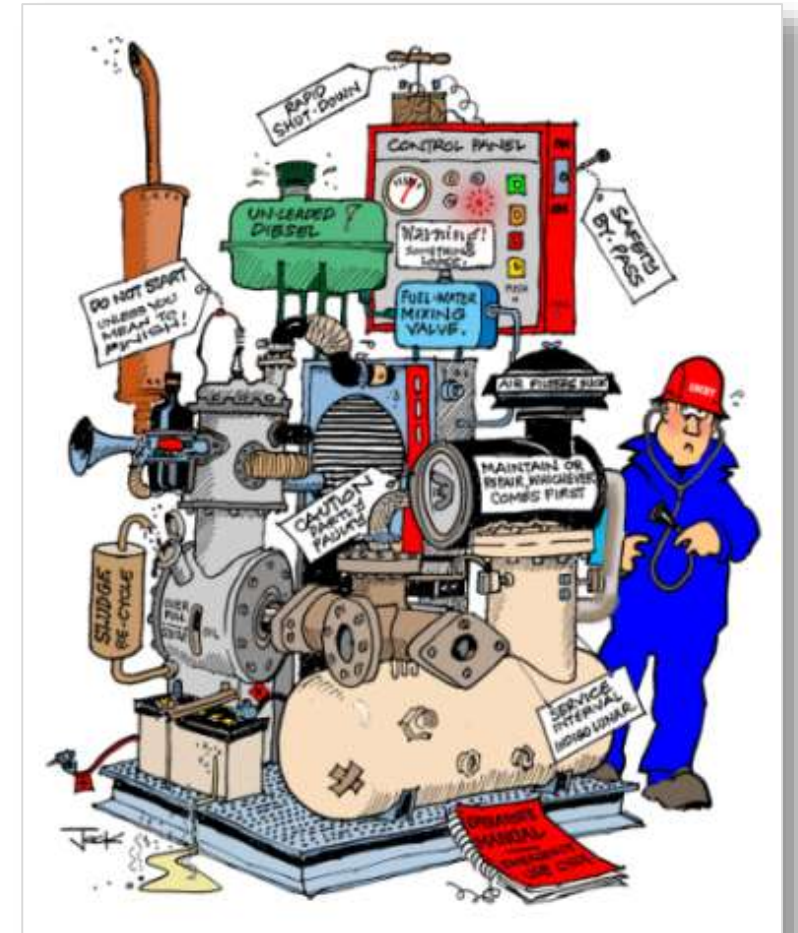
1/5000

**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



MathWorks®

# Industrial Internet of Things

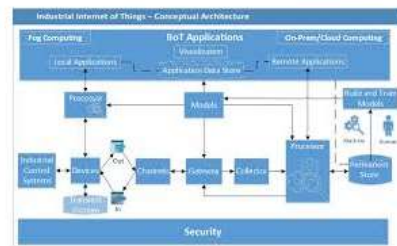
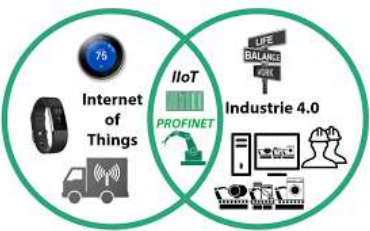
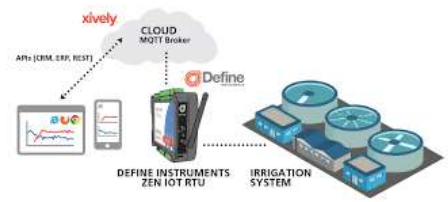
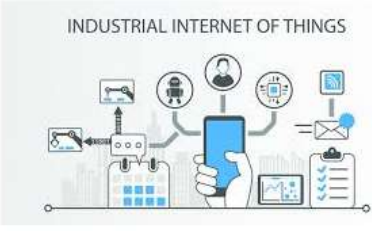
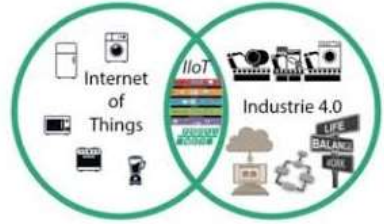
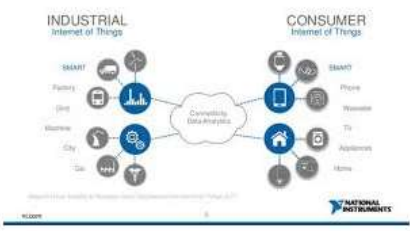
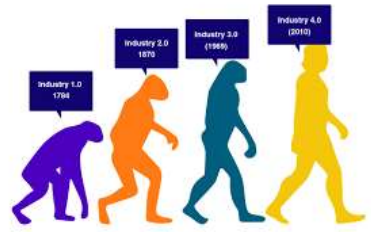
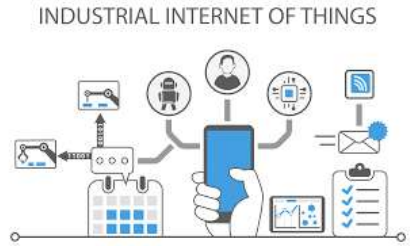
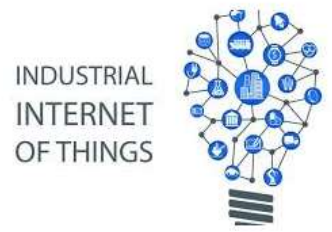
Search bar containing the text "iiot" with camera, microphone, and search icons.

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Settings Tools

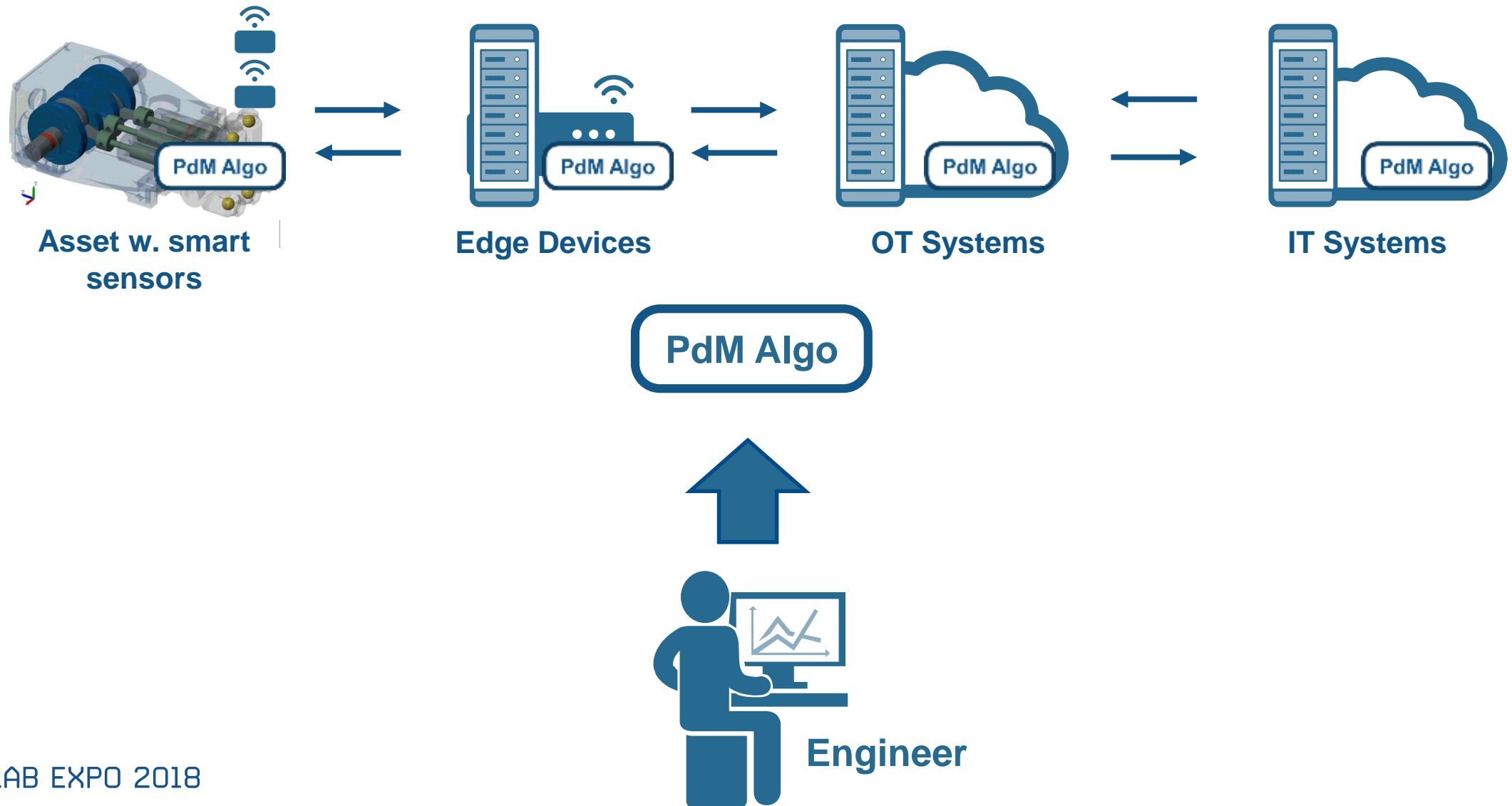
View saved SafeSearch

- production
- industrial iot
- iiot industrial**
- things iiot
- industrial internet





# Industrial Internet of Things



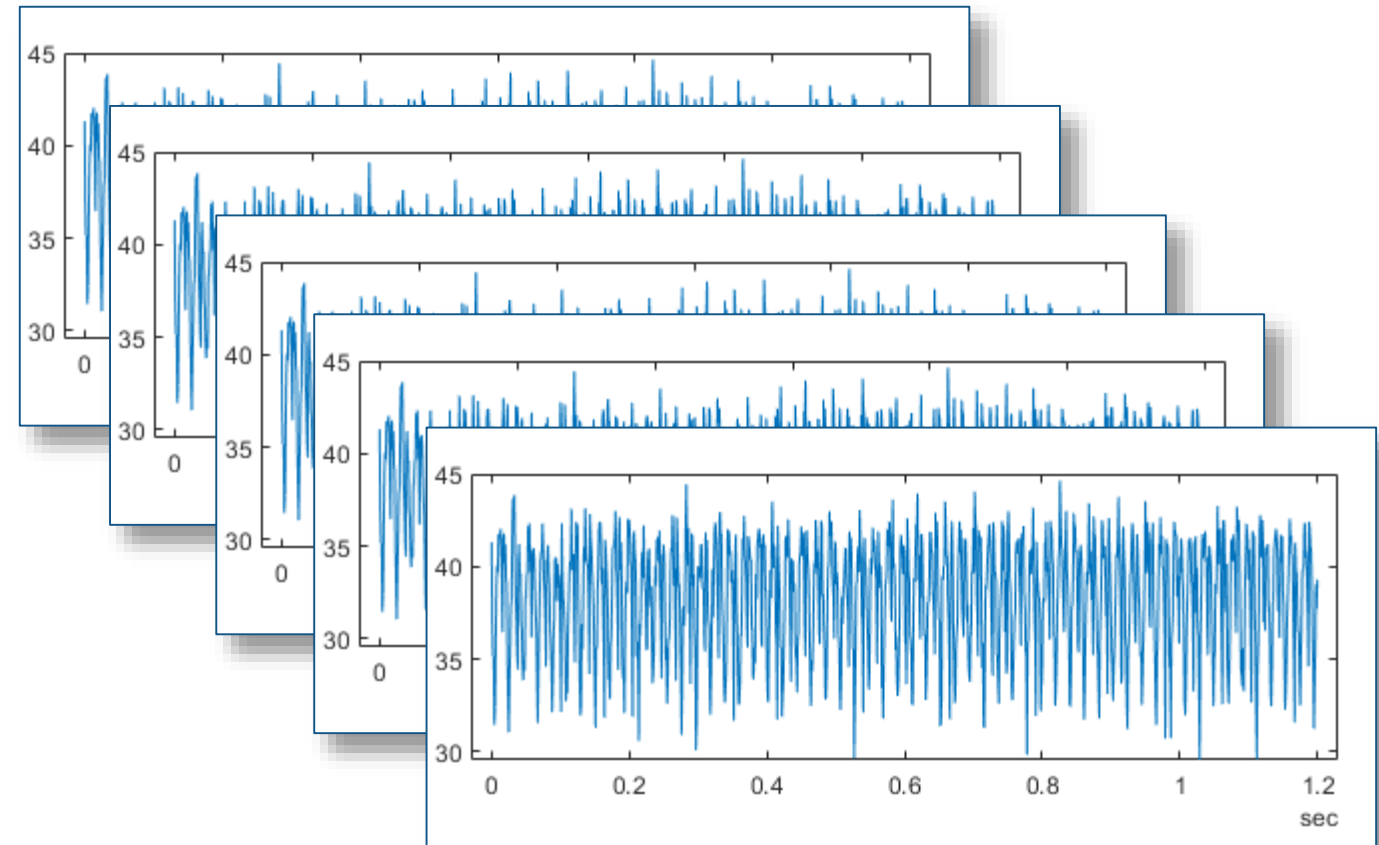
# Why MATLAB & Simulink for Predictive Maintenance

- Get started quickly
- Reduce the amount of data you need to store and transmit
- Deliver the results of your analytics based on your audience
- Create training data for your algorithm in the absence of real failure data

# Challenges: How much data are you collecting?

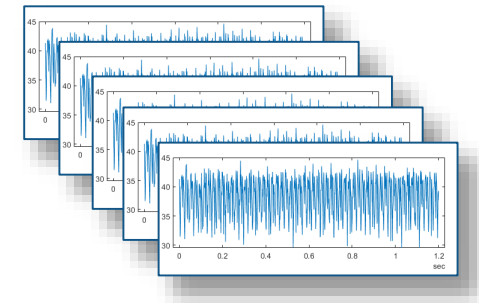
- 1 day ~ 1.3 GB
- 20 sensors/pump ~26 GB/day
- 3 pumps ~ 78 GB/day
- Satellite transmission
  - Speeds approx. 128-150 kbps,
  - Cost \$1,000/ 10GB of data
- Needle in a haystack problem

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



# Solution: Feature extraction at the Edge

- How do you extract features?
- Which features should you extract?
- How do I deal with streaming data?



**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

Current Folder

C:\Users\abaru\Desktop\Expo 2018\FinalDemo\Demo\_Files\Data\_Reduction

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

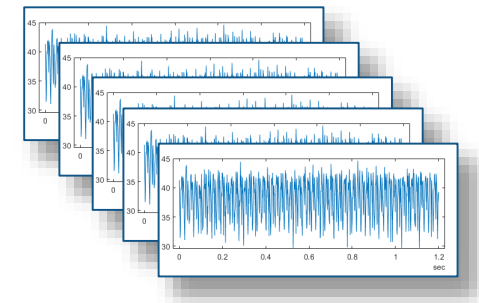
The model is configured to log the pump output pressure, output flow, motor speed and motor current.

```
1 ens = simulationEnsembleDatastore('..\Data');
2 ens.SelectedVariables = ["qOut_meas", "SimulationInput"];
3 reset(ens)
4 data = read(ens);
5 [flow,time_unit] = preprocess(data);
6 figure;
7 plot(flow.Time,flow.Data);

8 % Decide which features to extract
9
10 ens.DataVariables = [ens.DataVariables; ...
11     "qMean"; "qVar"; "qSkewness"; "qKurtosis"; ...
12     "qPeak2Peak"; "qCrest"; "qRMS"; "qMAD"; "qCSRange"];
13 ens.ConditionVariables = ["Time_Unit"];
14
15 feat = extractCI(flow);
16 dataToWrite = [time_unit, feat];
17 writeToLastMemberRead(ens,dataToWrite{:})
```

# 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



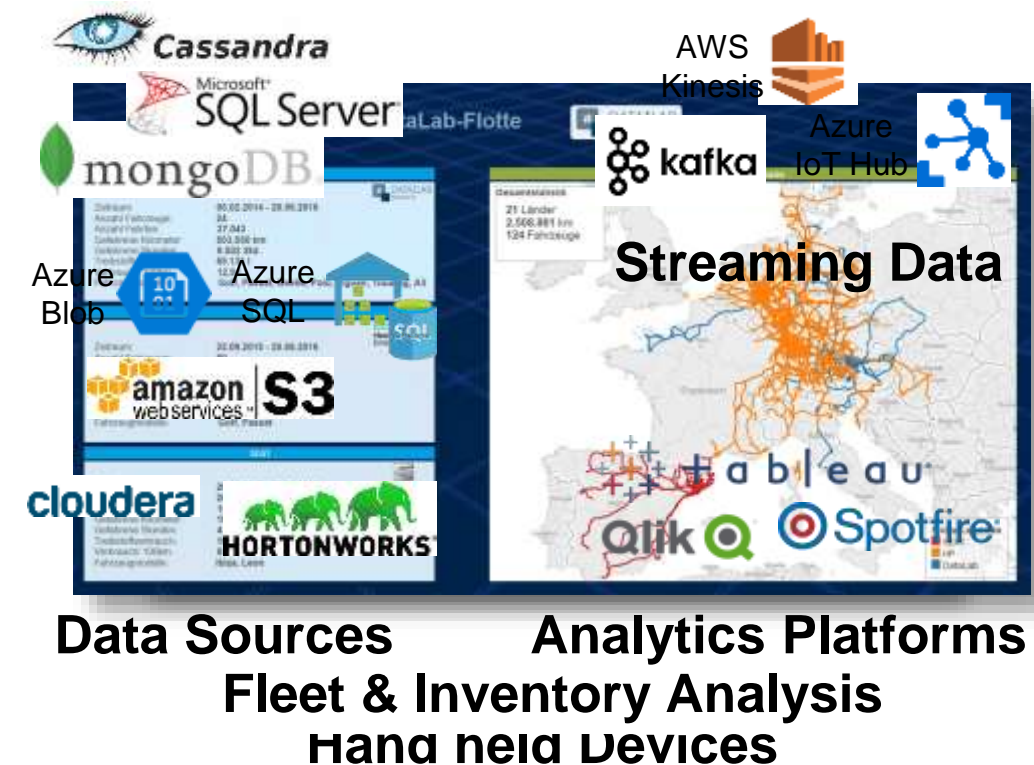
**Edge Devices**



qMean	qVar	qSkewness	qKurtosis
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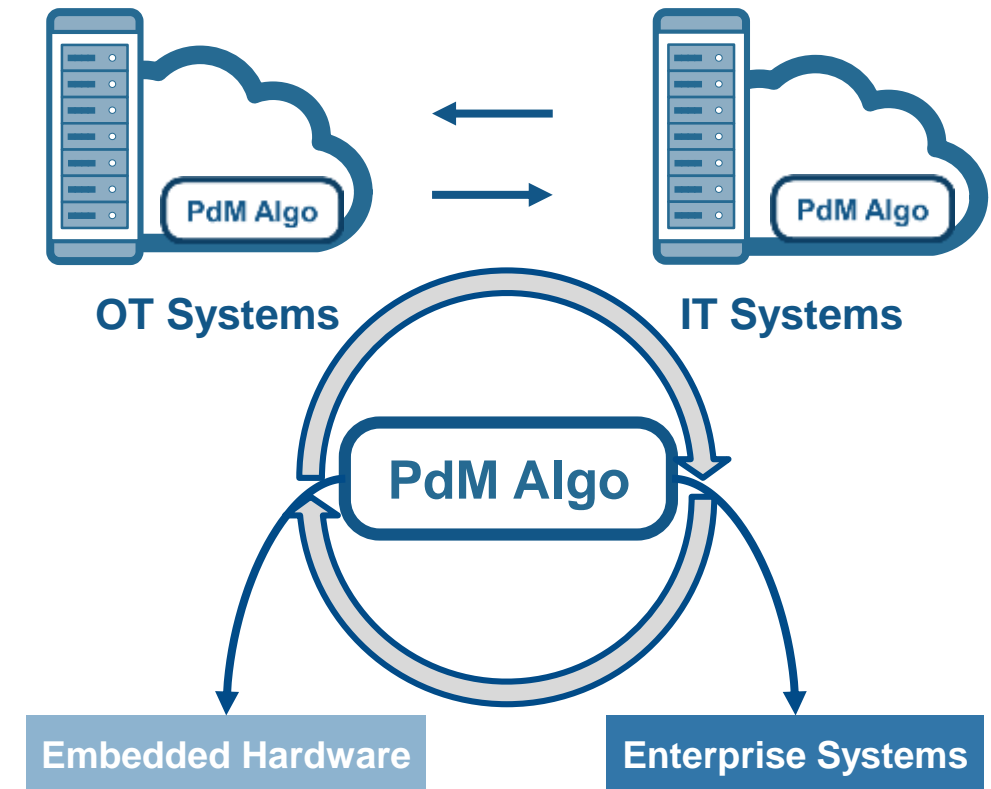
# Challenges: What do your end users expect?

- 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

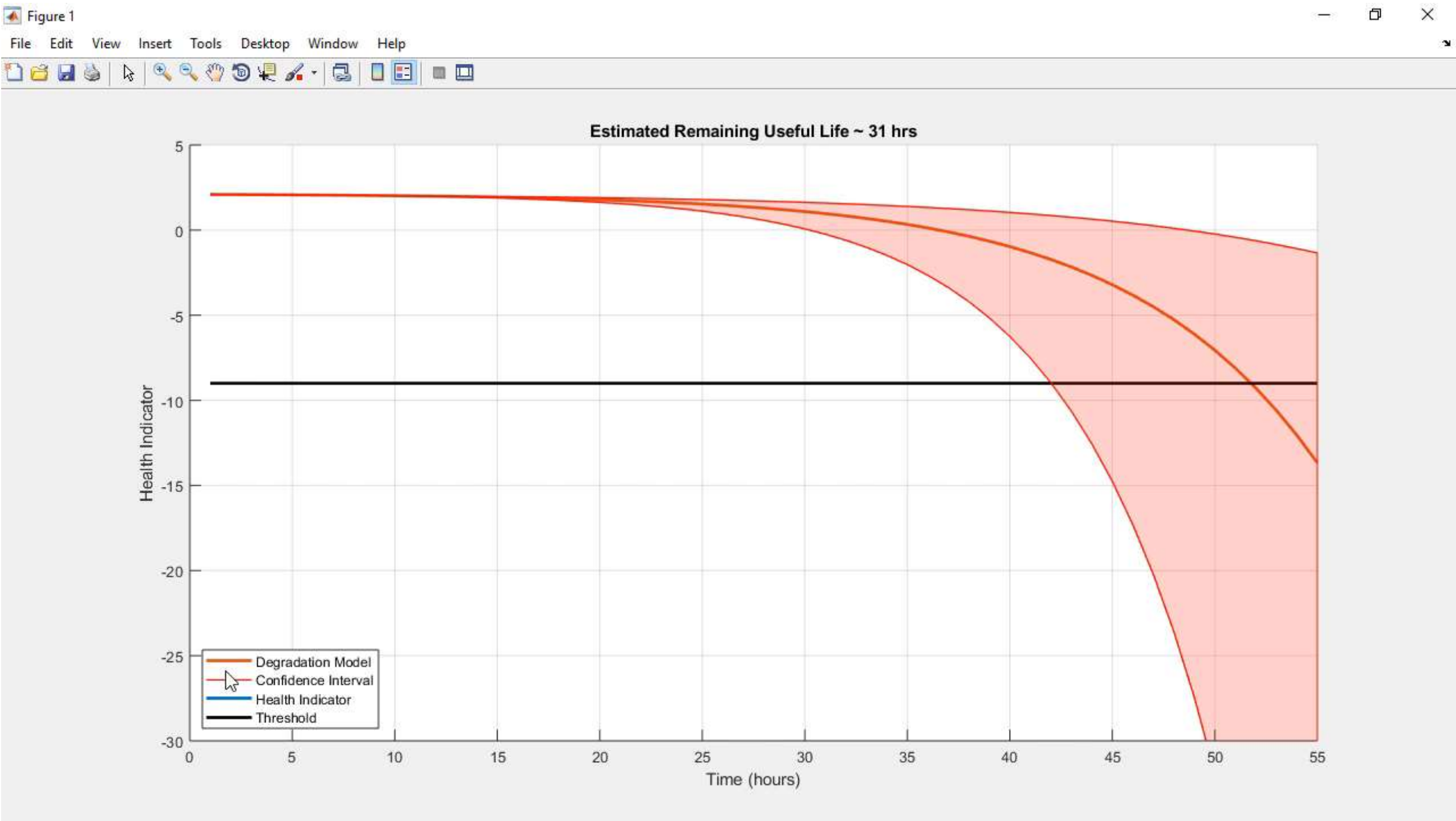


## Solution: Flexible deployment of algorithms

- Can I reuse my algorithm code for deployment?
- How do I update my predictive model?
- How do I integrate with my IT/OT systems?

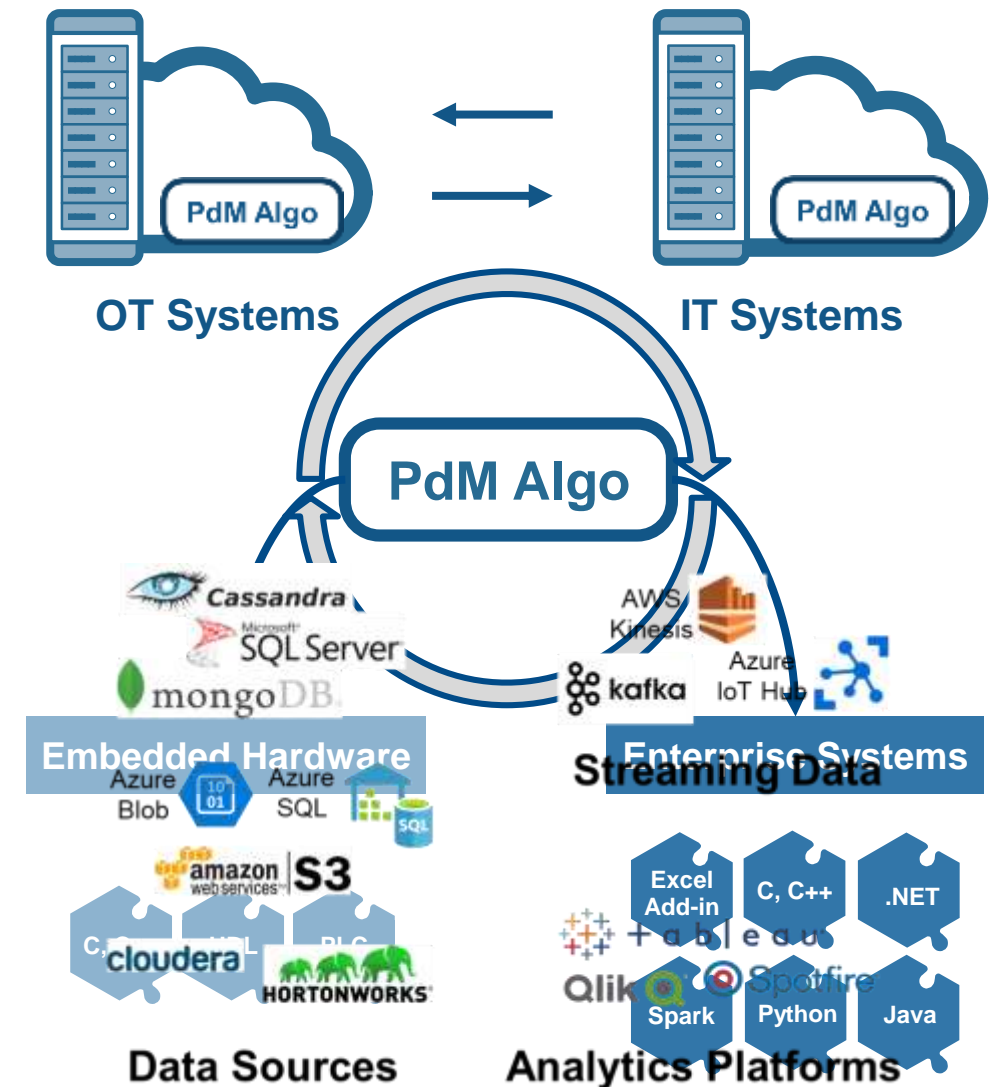






# Solution: Flexible deployment of algorithms

- 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



## 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?
- How do I customize a generic model to a specific machine?
- How do I know if the data is accurate?

File Explorer Simulation View Tools Help



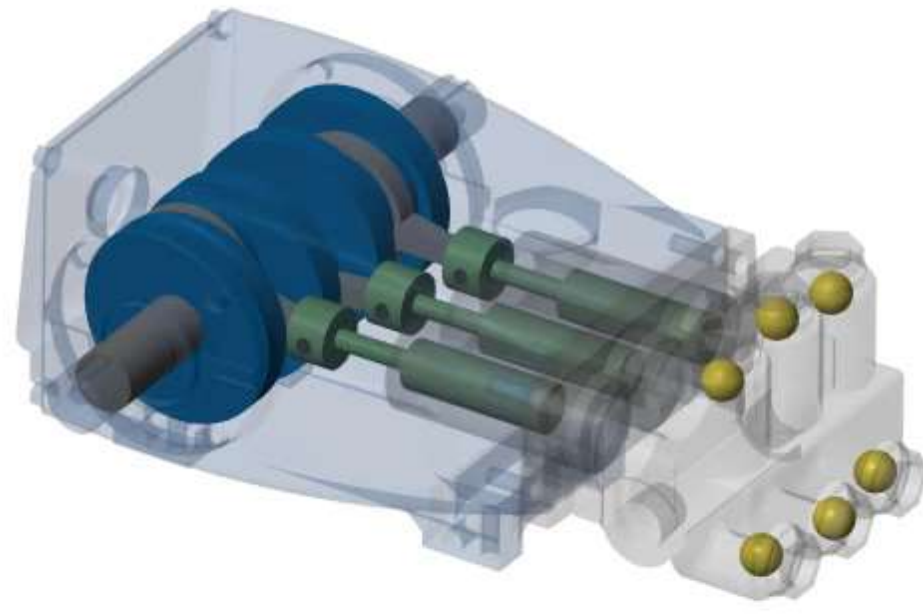
View convention: Z up (XY Top)

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

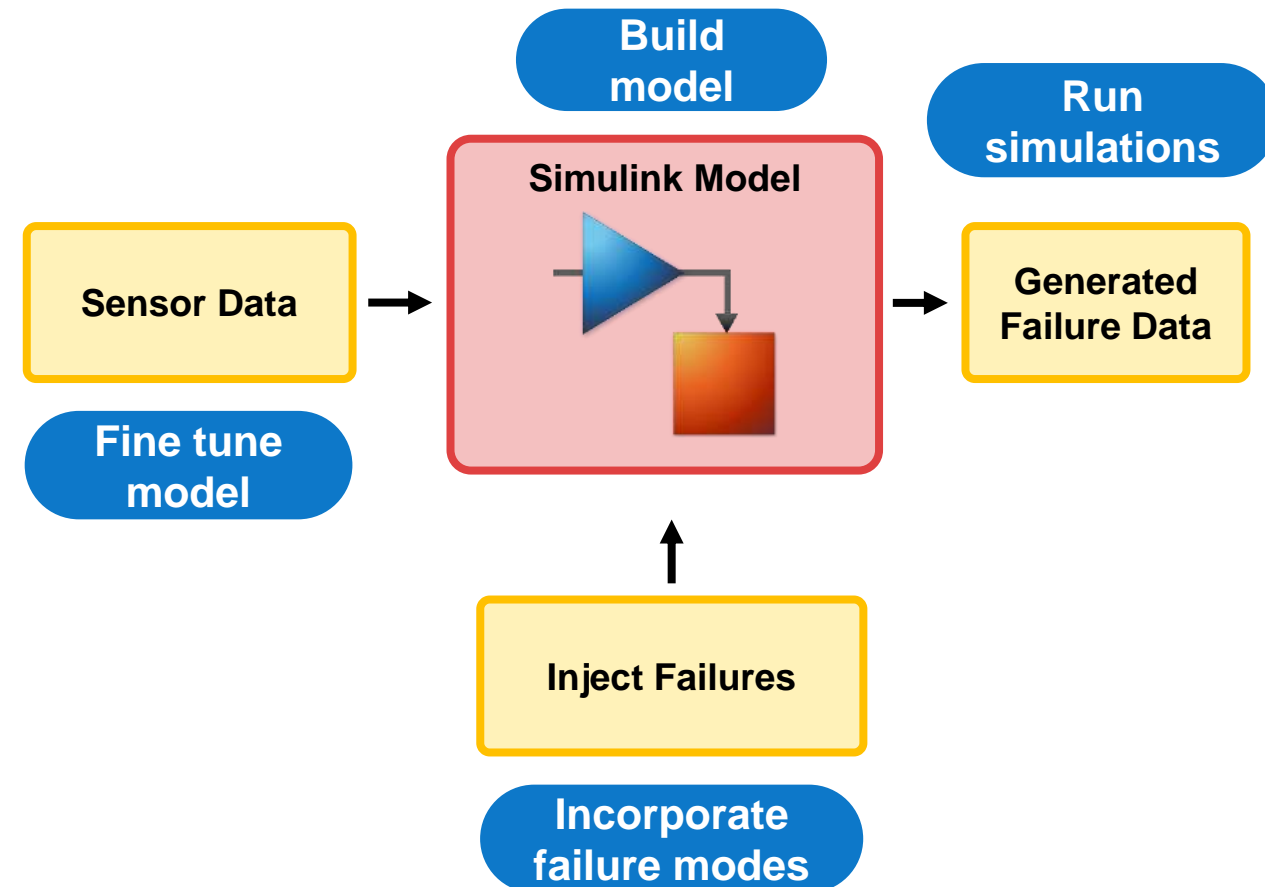
Time 1.5

Command Window

&gt;&gt;

# 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
- How do I know if the data is accurate?



# Solution: Generating failure data from Simulink models

- How do I know if the data is accurate?
  - Work
  - available
  - Vary
- How do I know if the data is accurate?
  - Fine
  - Valid
- How do I know if the data is accurate?



“Essentially, all models are wrong,  
but some are useful”

George E.P. Box

Inject Failures

3. Incorporate  
failure modes

4. Run  
simulations

Generated  
Failure Data

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