What is Predictive Maintenance?
I need help.
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

Asset w. smart sensors

Edge Devices

OT Systems

IT Systems

PdM Algo

Engineer

MATLAB EXPO 2018
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?
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.

```matlab
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);```
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
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?
Estimated Remaining Useful Life ~ 31 hrs

Graph showing the degradation model and confidence interval with a threshold. The health indicator decreases over time, indicating the remaining useful life of the system. The graph also shows the health indicator and the threshold level.
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?
Video for Simulink fault data
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 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
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- How do I know if the data is accurate?

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

  George E.P. Box

1. Build model
2. Fine tune model
3. Incorporate failure modes
4. Run simulations

Generated Failure Data
Inject Failures
3. Incorporate failure modes
4. Run simulations

Inject Failures
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