What is Predictive Maintenance?
I need help.
I need help. One of my cylinders is blocked. Your pump might fail in 15 hours.
What Does a Predictive Maintenance Algorithm Do?

- **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

I need help.

One of my cylinders is blocked.

Your pump might fail 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?

“...Subject Matter Expert Familiarity...”

“... [MATLAB is] Popular across the company...”
Workflow for Developing a Predictive Maintenance Algorithm

Acquire Data → Preprocess Data → Identify Features → Train Model → Deploy & Integrate
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
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
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
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
Daimler are Using MATLAB Today for Anomaly Detection

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

Near real-time decisions

- Time critical decisions
- Processing on historical big data

Value of data to decision making

- Preventive / Predictive
- Actionable
- Reactive
- Historical

Time:
- Real-Time
- Seconds
- Minutes
- Hours
- Days
- Months
Video showing Codegen with MATLAB Coder

```matlab
function [feature_list] = featureExtractionBuffer(data, timestamp)

persistent flow_array
persistent time_array
Np = 1000;
if isempty(flow_array)
    flow_array = NaN(Np, 1);
end
if isempty(time_array)
    time_array = NaN(Np, 1);
end
flow_array = [data; flow_array(1:Np-1)];
data = flow_array;

flow = data;
if isempty(find(isnan(data), 1))
    flow = data;
end

% Ensure the flow is sampled at a uniform sample rate
flow = (flow - timestamps);
```
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
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
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

- 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
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

“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
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
**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
Predictive Maintenance Architecture on Azure

**Edge**
- Generate telemetry

**Production System**
- MATLAB Production Server
  - Worker processes
  - Request Broker
- Apache Kafka
- State Persistence
- System Architect
- Storage Layer

**Analytics Development**
- MATLAB Compiler SDK
- MATLAB
- Debug
- Package & Deploy
- Algorithm Developers

**Business Decisions**
- Business Decisions
- Presentation Layer
- End Users
Predictive Maintenance Architecture on Azure

- **Databases**
  - Cassandra
  - SQL Server
  - MongoDB

- **Cloud Storage**
  - Azure Blob
  - Azure SQL
  - Amazon S3

- **Big Data / OT Platforms**
  - Cloudera
  - Hortonworks
  - OSIsoft PI System

- **Production System**
  - MATLAB Production Server
    - Worker processes
  - Request Broker
    - Debug
  - State Persistence
  - Storage Layer

- **Analytics Development**
  - MATLAB Compiler SDK
  - MATLAB
  - Package & Deploy
  - Debug
  - Model
  - System Architect

- **Streaming**
  - AWS Kinesis
  - Kafka

- **OT Platforms**
  - OSIsoft PI System

- **Dashboards**
  - Microsoft Power BI
  - Qlik
  - Spotfire

- **End Users**
  - Qlik
  - kibana
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
MathWorks can help you get started **TODAY**

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