End-to-end algorithm development for predictive maintenance

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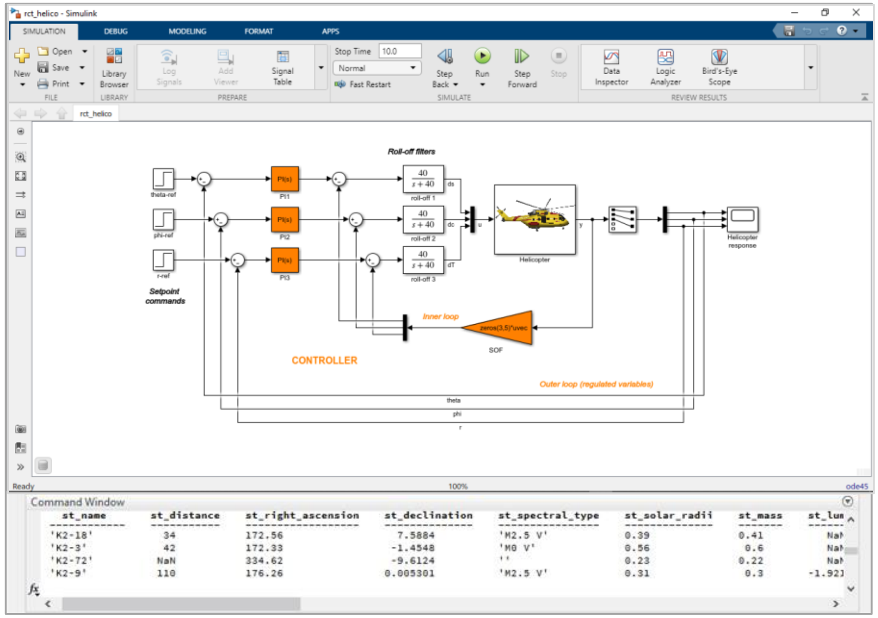
MathWorks

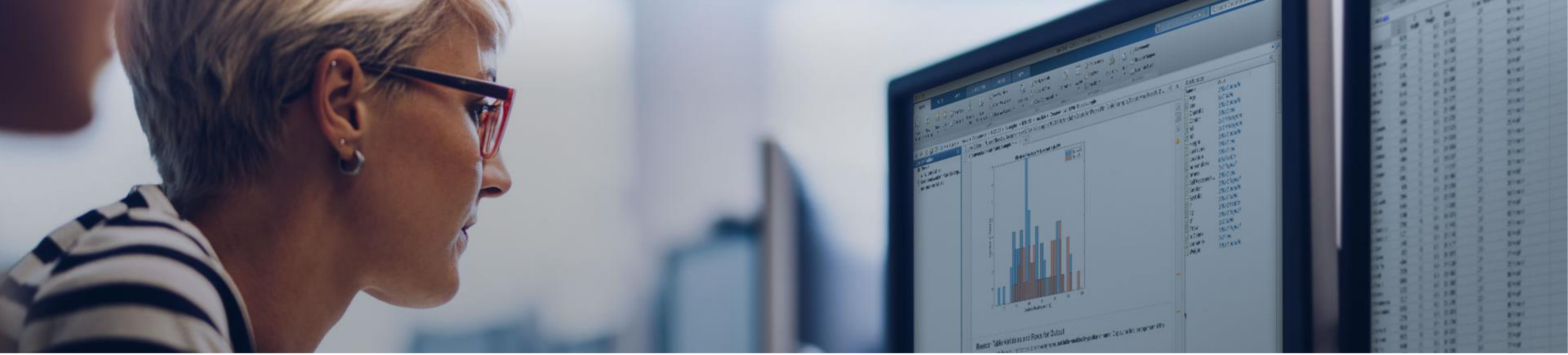
Our Products

MATLAB & SIMULINK

- MATLAB is a programming environment for algorithm development, data analysis, visualization, and numeric computation.
- Simulink is a graphical environment for designing, simulating, and testing systems.
- More than 100 add-on products for specialized tasks.

Computer Vision Toolbox
Simulink
MATLAB





- Millions of engineers and scientists worldwide use MATLAB and Simulink.

4 million+
users in 185 countries

100,000+
businesses, governments, and universities

All of the top 10 automotive and aerospace companies

OICA: 2017 World Motor Vehicle Production
PwC: Aerospace and Defense 2018 Year in Review

Knowing AI is an asset

The Chairman of Nokia on Ensuring Every Employee Has a Basic Understanding of Machine Learning — Including Him

by Risto Siilasmaa

October 04, 2018

- Harvard Business Review

AI skills is a major concern

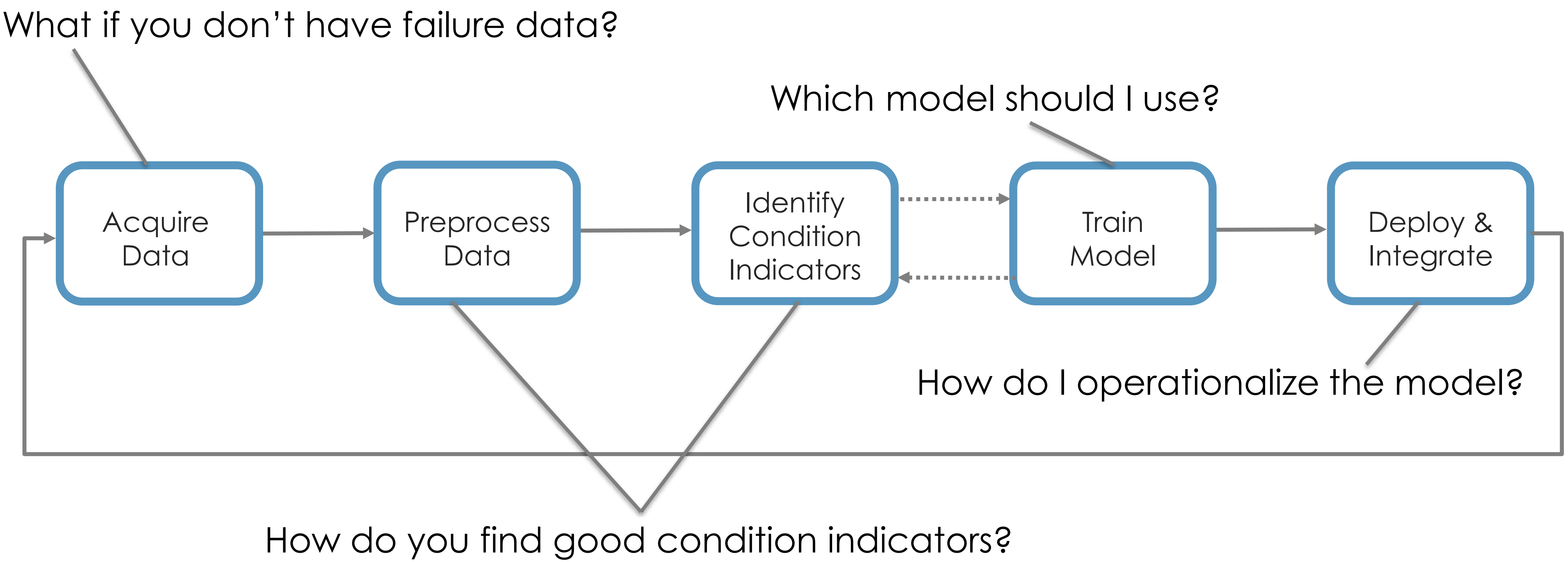
n = 106
Gartner Research Circle members, excluding "unsure"
Source: Gartner AI and ML Development Strategies Survey
Q: What are the top three challenges or barriers to the adoption of AI and ML within your organization?
Rank up to three.
ID: 390794

Skills of staff is the top challenge for organizations surveyed by Gartner*

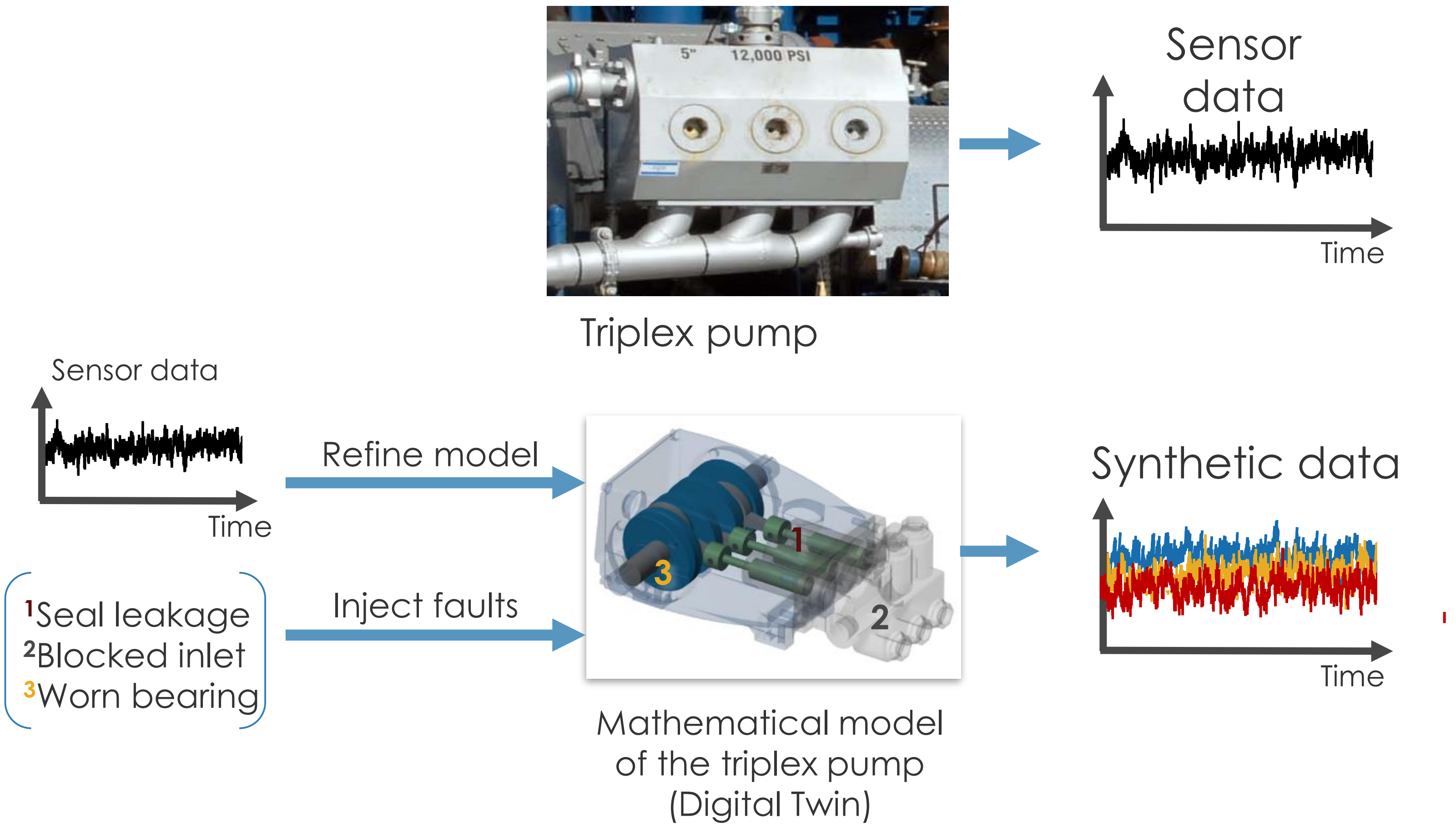
*Source: "AI and ML Development Strategies, Motivators and Adoption Challenges," Gartner Research Note, published 19 June 2019

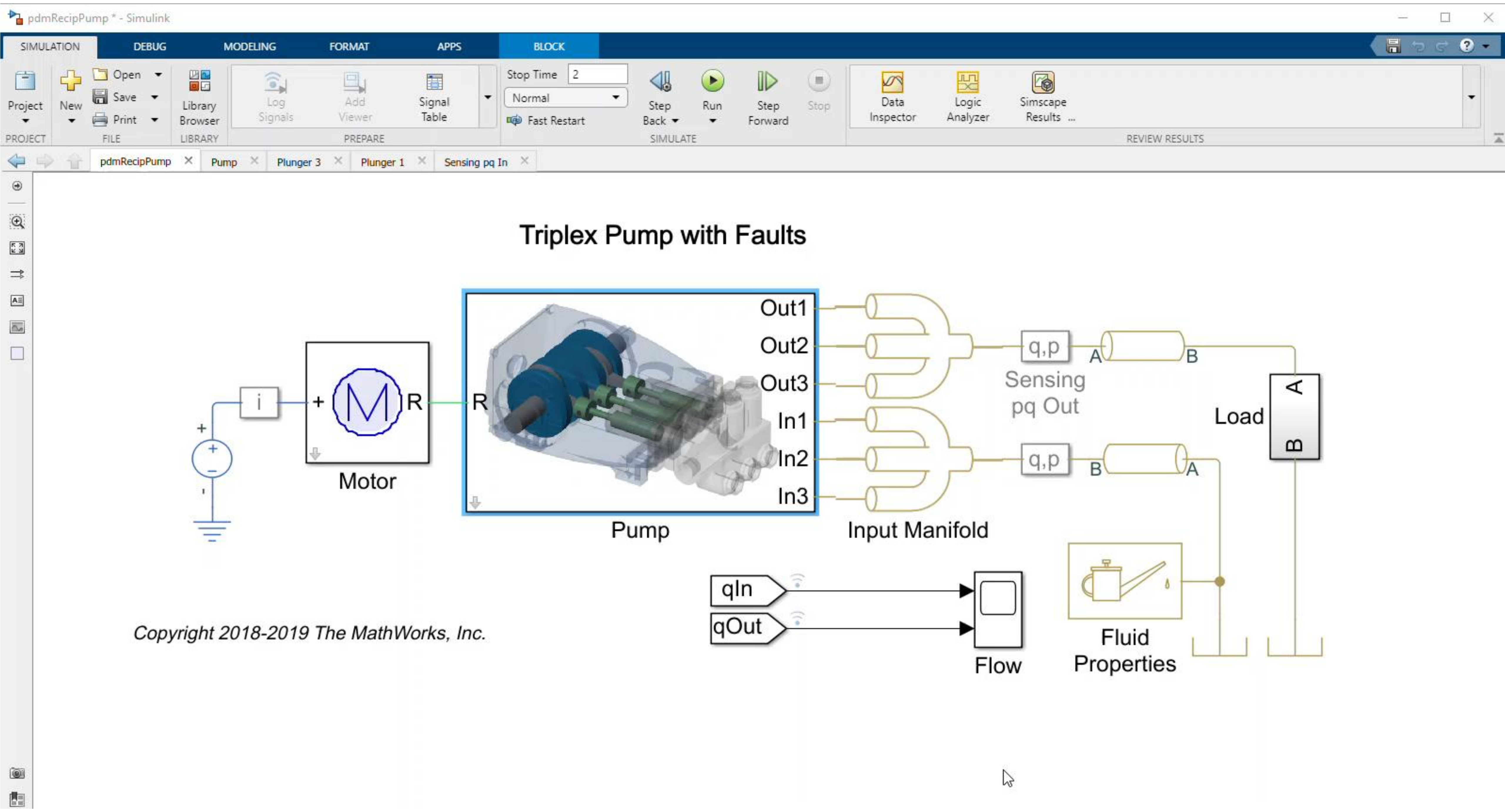
Tools for every skill level needed

Workflow for Developing a Predictive Maintenance Algorithm



1. What if you don't have failure data?




pdmRecipPump * - Simulink
SIMULATION
DEBUG
MODELING
FORMAT
APPS
BLOCK
Project
New
Open
Save
Print
Library Browser
Log Signals
Add Viewer
Signal Table
Stop Time
2
Normal
Fast Restart
Step Back
Run
Step Forward
Stop
Data Inspector
Logic Analyzer
Simscape Results
PROJECT
FILE
LIBRARY
PREPARE
SIMULATE
REVIEW RESULTS
pdmRecipPump
Pump
Plunger 3
Plunger 1
Sensing pq In
Triplex Pump with Faults
Out1
Out2
Out3
In1
In2
In3
Motor
Pump
Input Manifold
q,p
Sensing pq Out
Load
qIn
qOut
Flow
Fluid Properties
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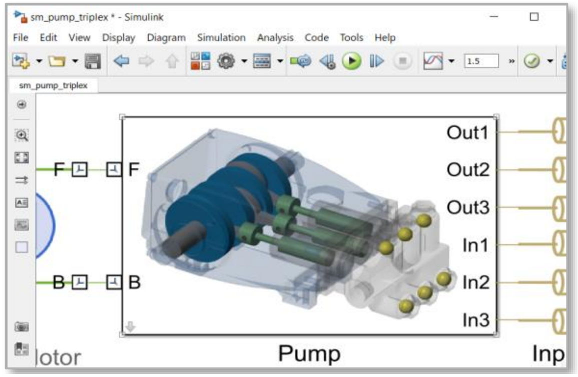
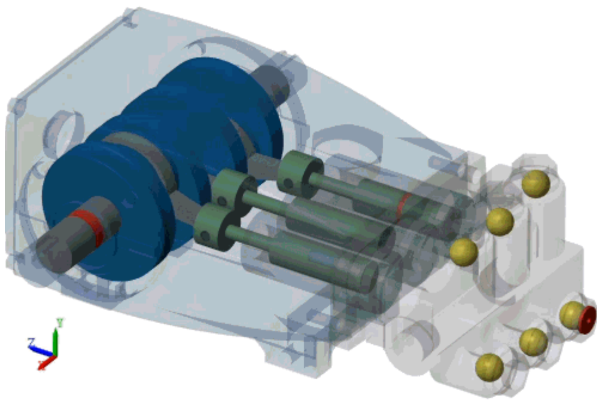
Simulate data for Condition monitoring with a Digital Twin

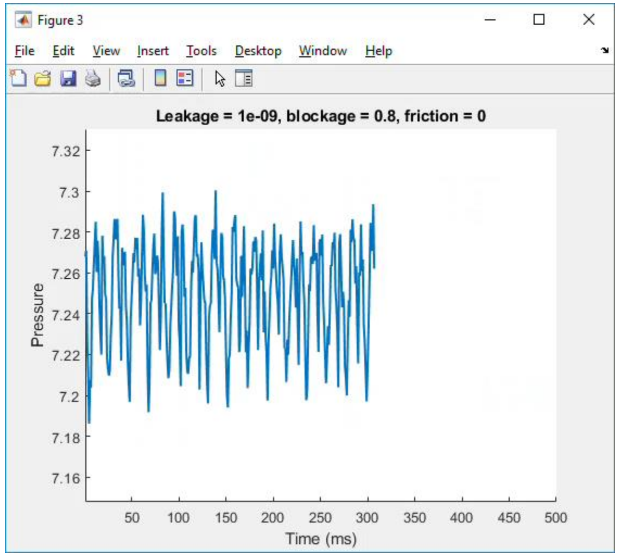


Leak Area = [1e-9 0.036]

Bearing Friction = [0 6e-4]

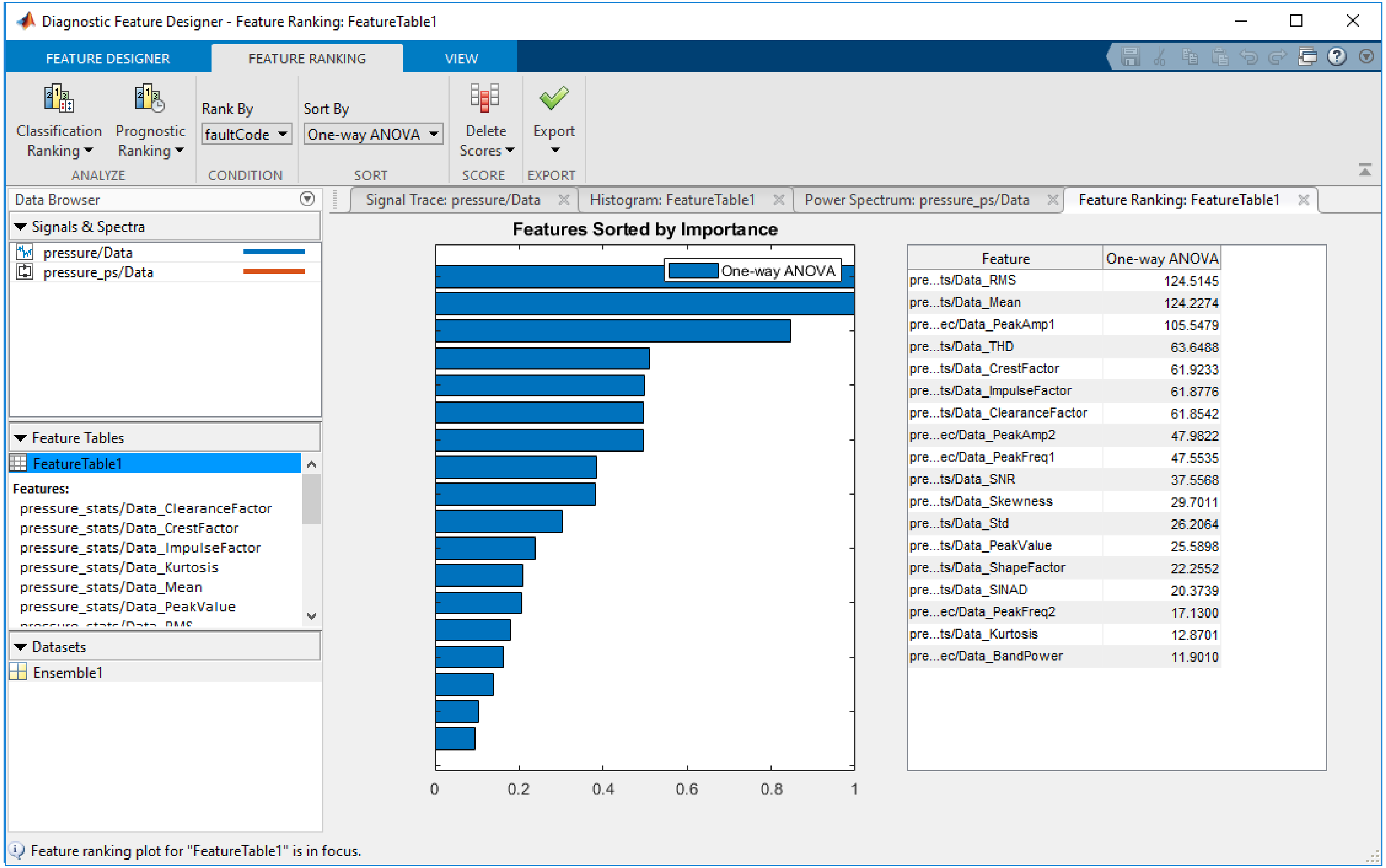
Blocking Fault = [0.3 0.8]





flow	pressure	faultCode
1201x1 timetable	1201x1 timetable	100
1201x1 timetable	1201x1 timetable	100
1201x1 timetable	1201x1 timetable	100
1201x1 timetable	1201x1 timetable	100
1201x1 timetable	1201x1 timetable	100
1201x1 timetable	1201x1 timetable	100
1201x1 timetable	1201x1 timetable	100
1201x1 timetable	1201x1 timetable	100
1201x1 timetable	1201x1 timetable	0
1201x1 timetable	1201x1 timetable	100
1201x1 timetable	1201x1 timetable	10
1201x1 timetable	1201x1 timetable	10
1201x1 timetable	1201x1 timetable	1
1201x1 timetable	1201x1 timetable	11
1201x1 timetable	1201x1 timetable	11
1201x1 timetable	1201x1 timetable	10
1201x1 timetable	1201x1 timetable	1

2. How do you find good condition indicators?



3. Which Machine Learning model should I use?

Use case 1: Fault Classification

Why is my machine behaving abnormally?

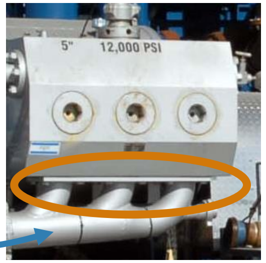
Condition Monitoring

Condition indicators

Classifier

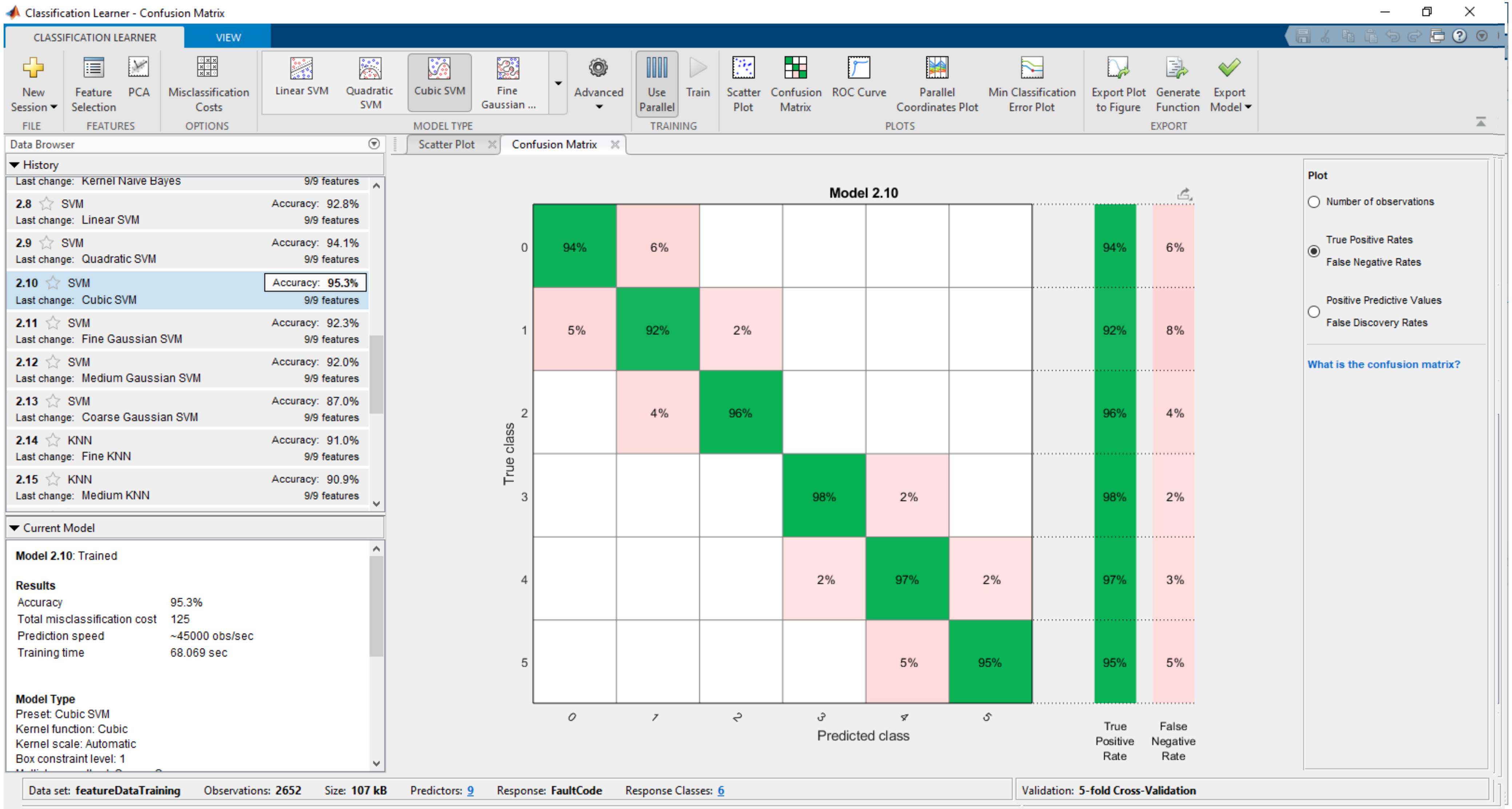
Identify fault type

- Healthy
- Blocked Inlet
- Seal Leakage
- Worn Bearing
- Blocked Inlet & Worn Bearing
- Seal Leakage & Worn Bearing
- Seal Leakage & Blocked Inlet



Determine what needs to be fixed

3. Which Machine Learning model should I use?

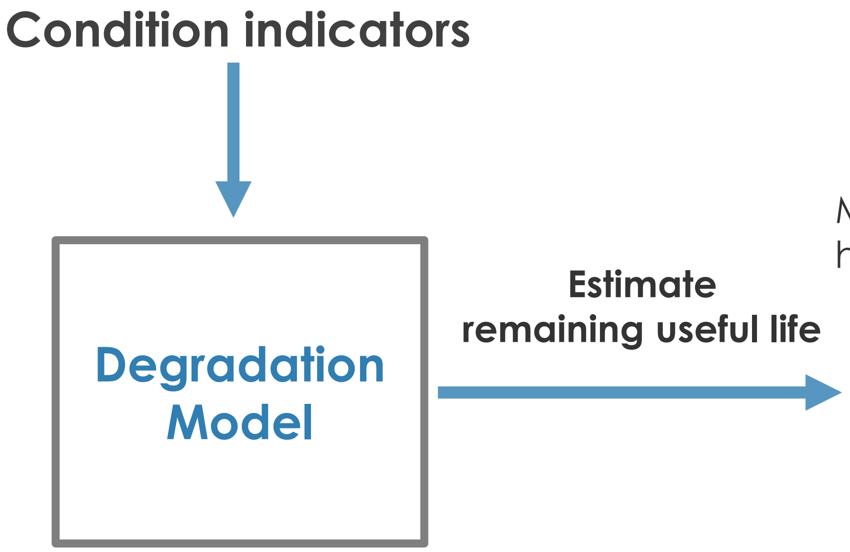


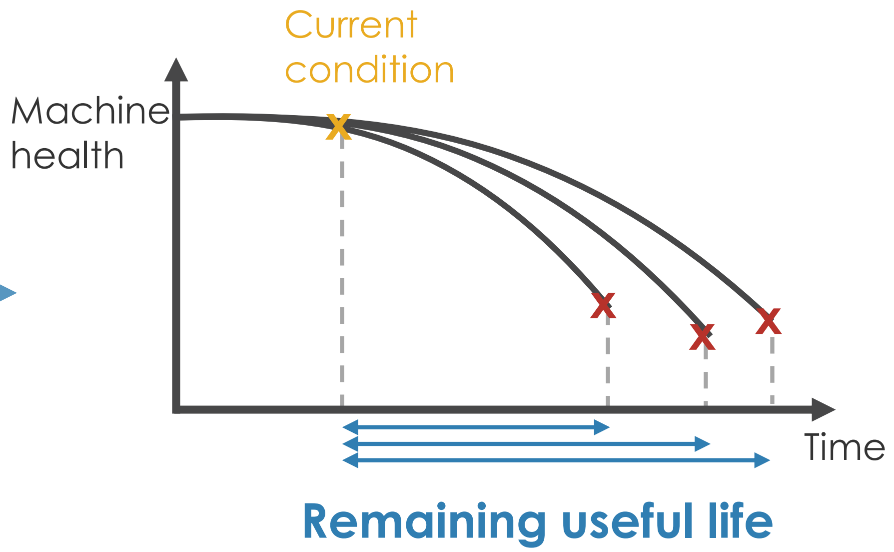
Remaining Useful Life Estimation

Use case 2: Prognostics

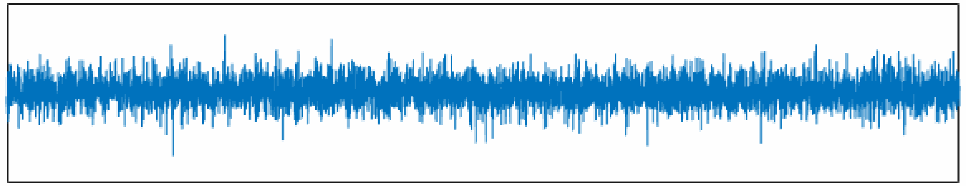
How much longer can I operate my machine ?

Remaining Useful Life Estimation

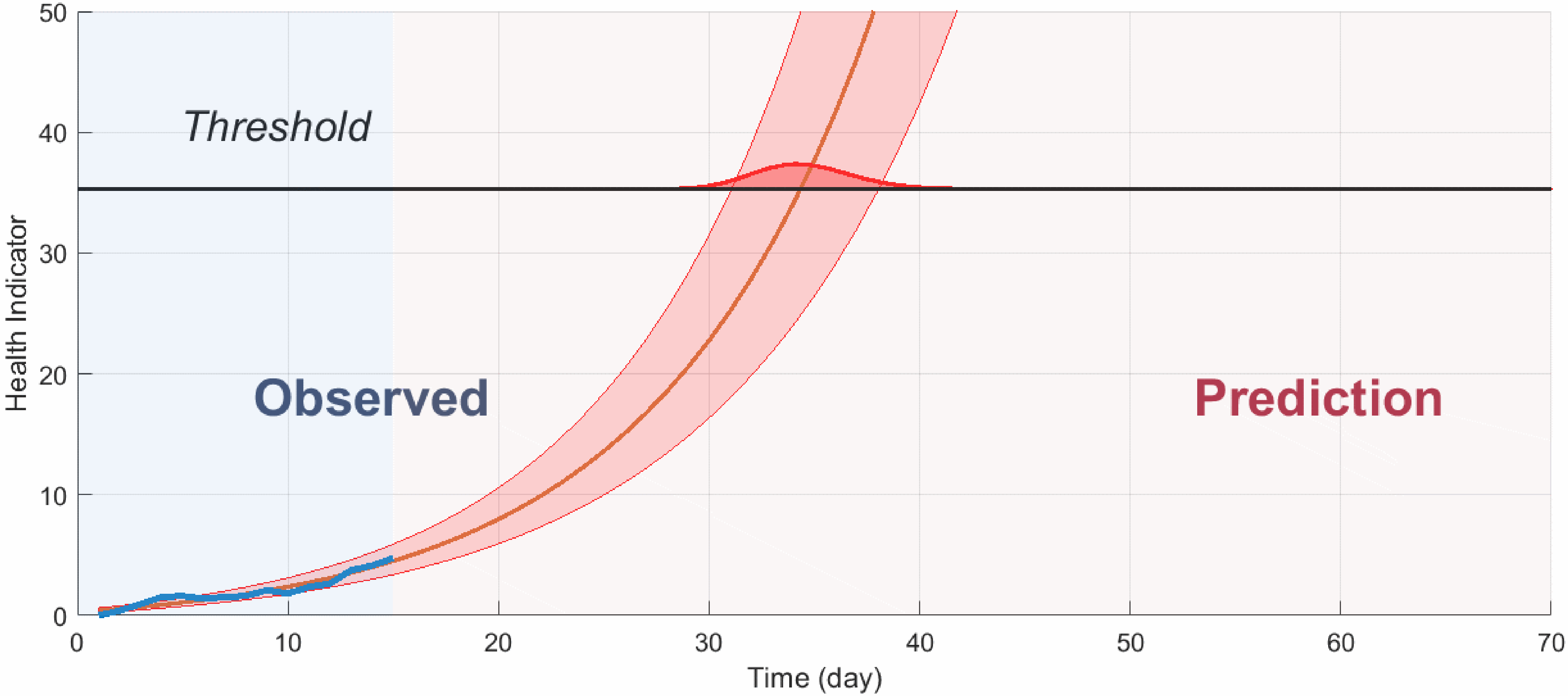




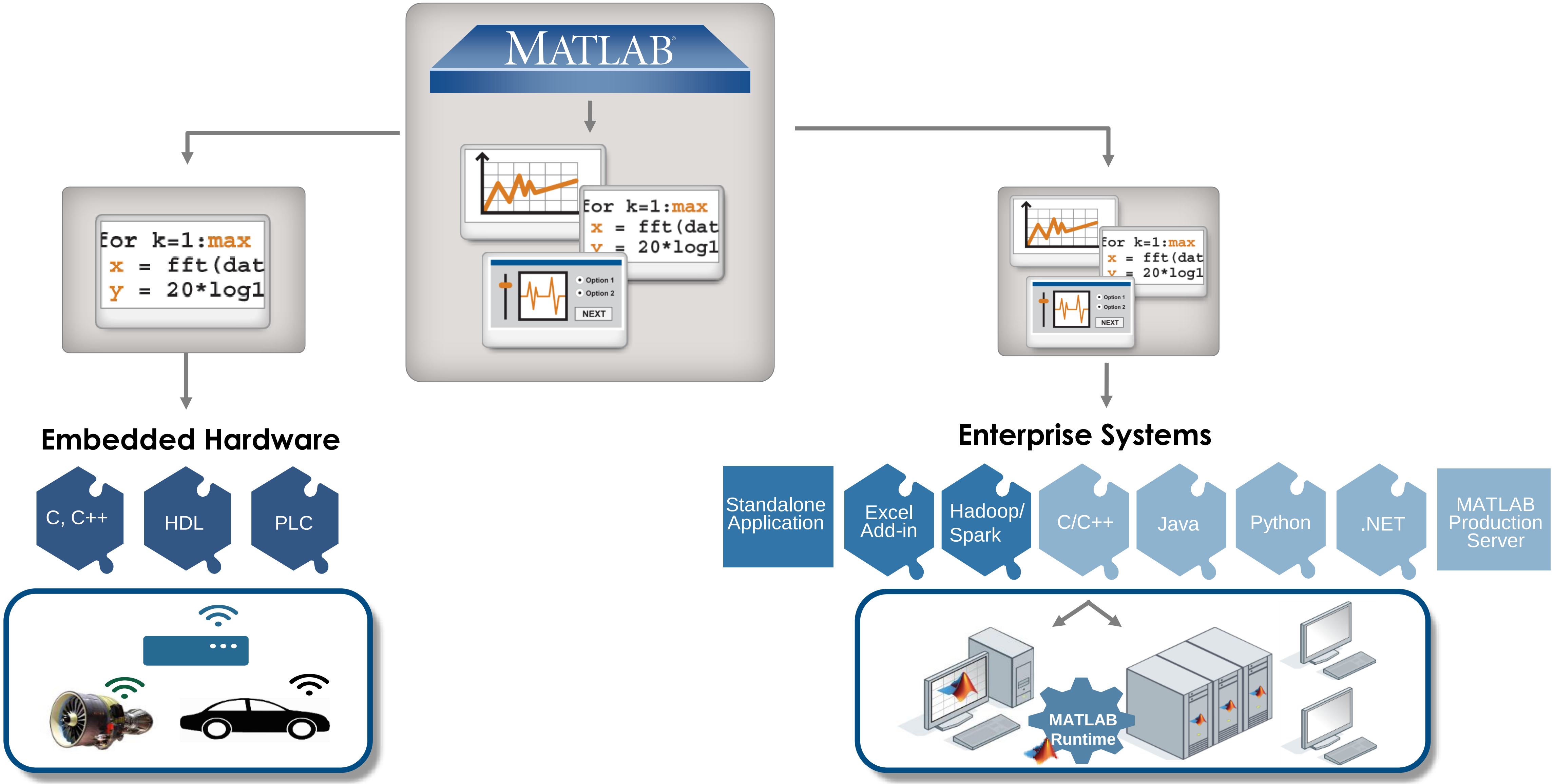
Remaining Useful Life Estimation



RUL: 459 hours
(95%CI: 374-558 hours)



4. How do I operationalize the model?



Enable your workforce to develop AI capabilities

BMW Uses Machine Learning to Detect Oversteering

Challenge

Develop automated software for detecting oversteering

Solution

Use interactive apps to quickly explore different machine learning models, and identify the most accurate one. Automatically generate C code for the model.

A BMW M4 oversteering on a test track.

Results

- Oversteering identified with greater than 98% accuracy
- Multiple machine learning classifiers trained automatically
- Model deployed to an ECU for real-time, in-vehicle testing

"Working in MATLAB, we developed a supervised machine learning model as a proof of concept. ***Despite having little previous experience with machine learning, in just three weeks we completed a working ECU prototype capable of detecting oversteering with over 98% accuracy."***

- Tobias Freudling, BMW Group

Link to article

MathWorks can help you get started **TODAY**

- [Examples]
- [Documentation]
- [Consulting]
- [Tech Talk Series]

Summary – enablers for Predictive Maintenance

1. Digital Twins can be used to generate missing failure data
   – Most companies designing machines already have simulation models

2. High-level language and apps speed-up development
   – Non-programmers and non-ML specialists can contribute

3. Specialized tools for various domains, e.g. Predictive Maintenance

4. Flexible deployment options
   – Embedded, edge or enterprise