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# Three Ways to Estimate Remaining Useful Life

Predictive Maintenance  
with MATLAB

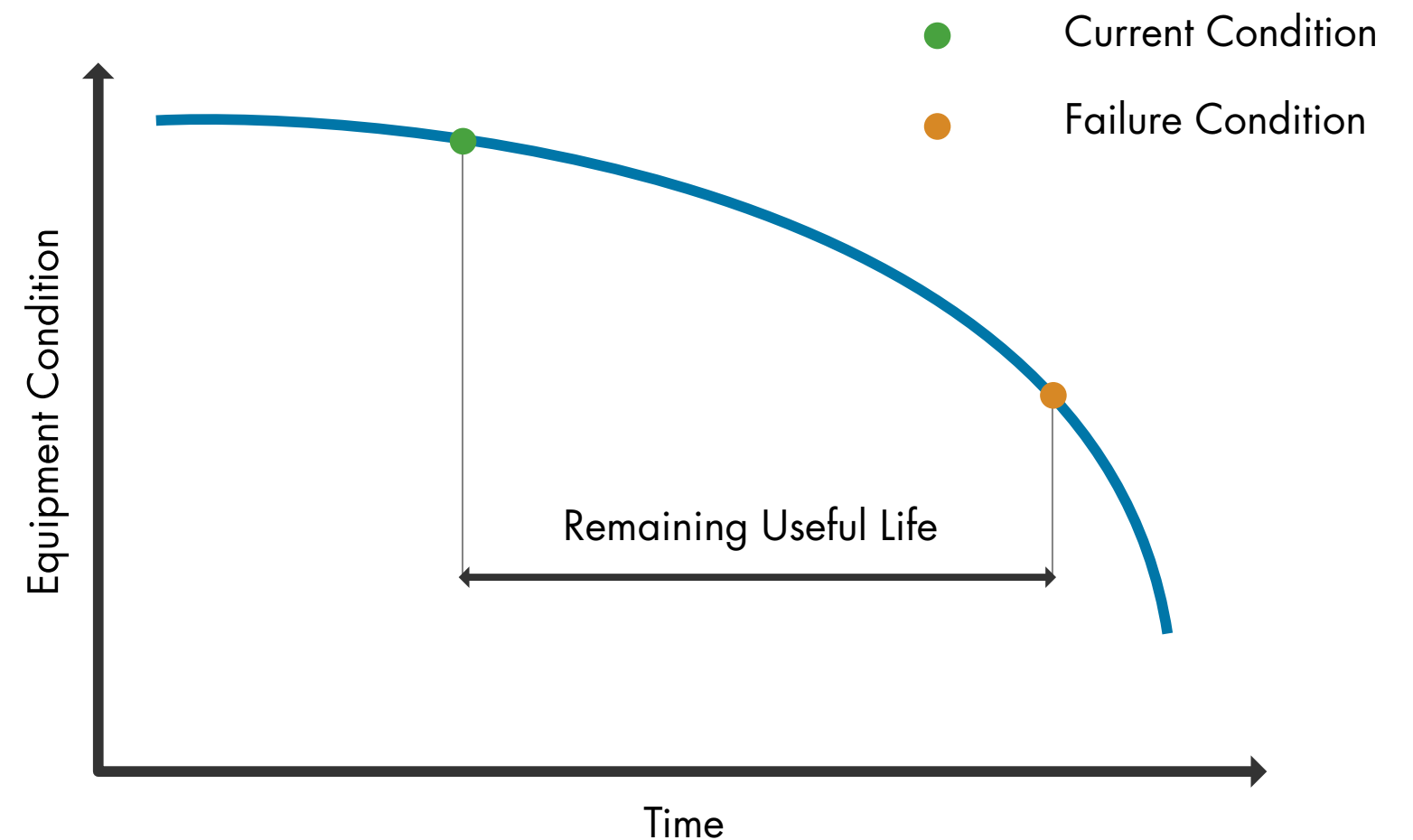
# What is remaining useful life?

Remaining useful life (RUL) is the length of time a machine is likely to operate before it requires repair or replacement.

By taking RUL into account, engineers can schedule maintenance, optimize operating efficiency, and avoid unplanned downtime.

For this reason, estimating RUL is a top priority in predictive maintenance programs.

## Equipment Deterioration Profile

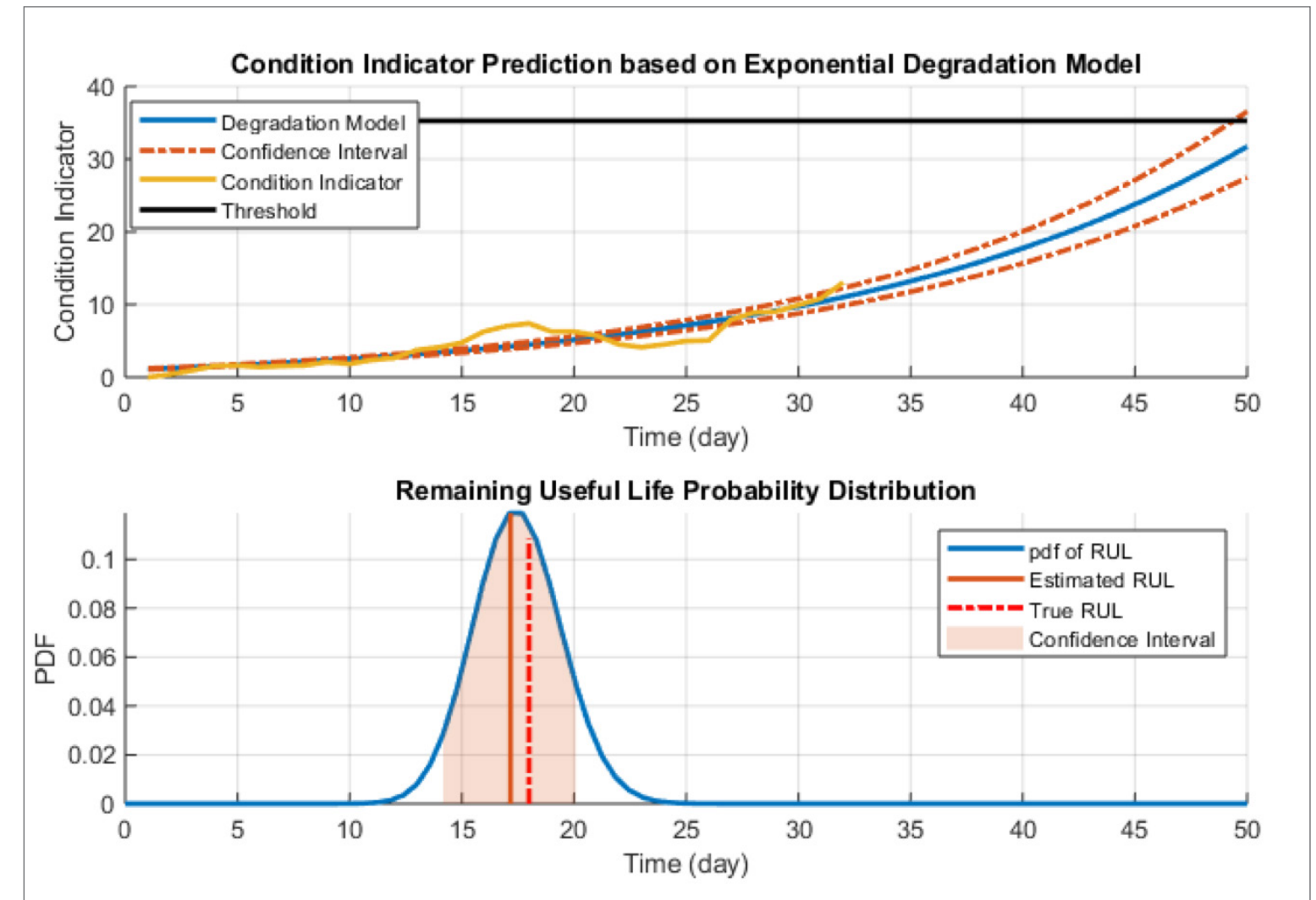


# Three Ways to Estimate RUL

The method used to calculate RUL depends on the kind of data available:

- Lifetime data indicating how long it took for similar machines to reach failure
- Run-to-failure histories of machines similar to the one you want to diagnose
- A known threshold value of a condition indicator that detects failure

*Predictive Maintenance Toolbox*<sup>™</sup> provides models for estimating RUL from each type of data.



*Training predictive models that can estimate remaining useful life and provide confidence intervals associated with the prediction.*

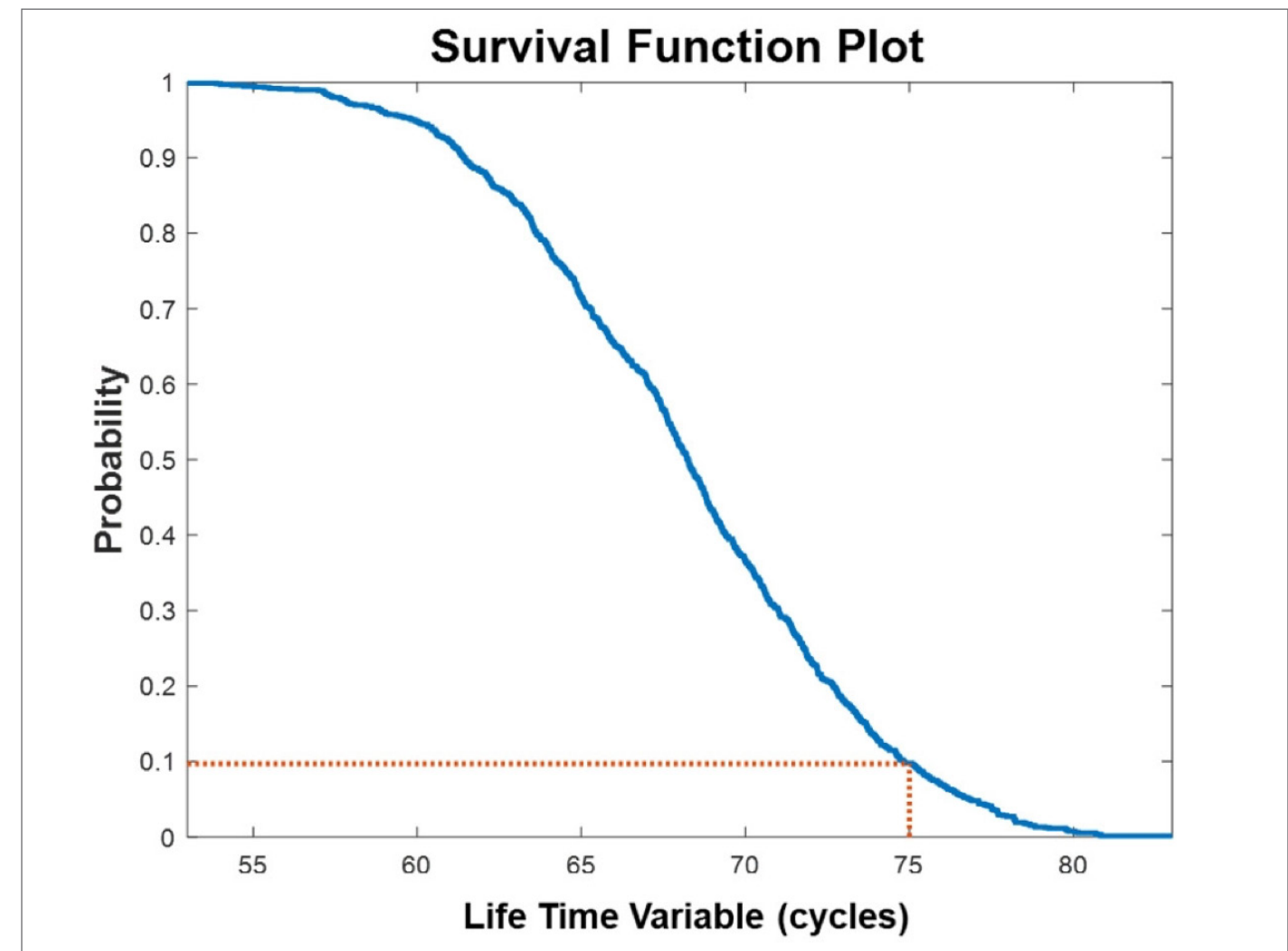
# 1. Using Lifetime Data to Estimate RUL

## *with Survival Models*

Proportional hazard models and probability distributions of component failure times are used to estimate RUL from lifetime data.

A simple example is estimating the discharge time of a battery based on past discharge times and covariates, variables such as the environment in which the battery operated (such as temperature) and the load placed on it.

Code example: [Battery Systems Using Survival Models](#)



*Survival function plot. At the end of 75 cycles, the probability of a battery's continuing to operate is 0.1, or 10%.*

## 2. Using Run-to-Failure Data to Estimate RUL

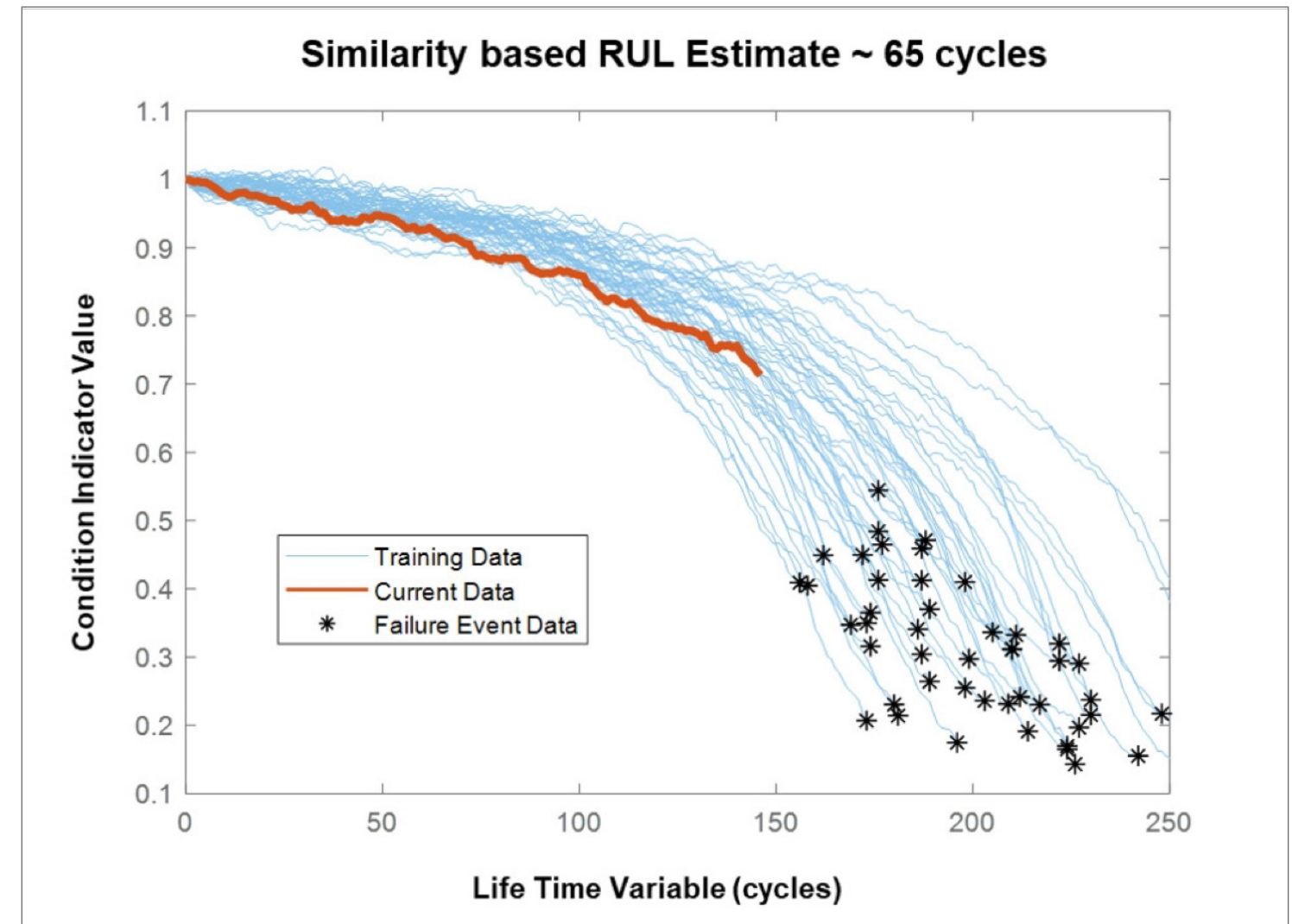
### *with Similarity Models*

If you have a database of run-to-failure data from similar components or different components showing similar behavior, you can estimate RUL using similarity methods.

These methods capture degradation profiles and compare them with new data coming in from the machine to determine which profile the data matches most closely.

Code example:

[Estimating RUL Using Run-to-Failure Data from an Engine](#)



Similarity models capture degradation profiles (blue) based on run-to-failure data. The distribution of the stars (or endpoints) of the nearest blue curves gives an RUL of 65 cycles for the current data (red).

# 3. Using Threshold Data to Estimate RUL

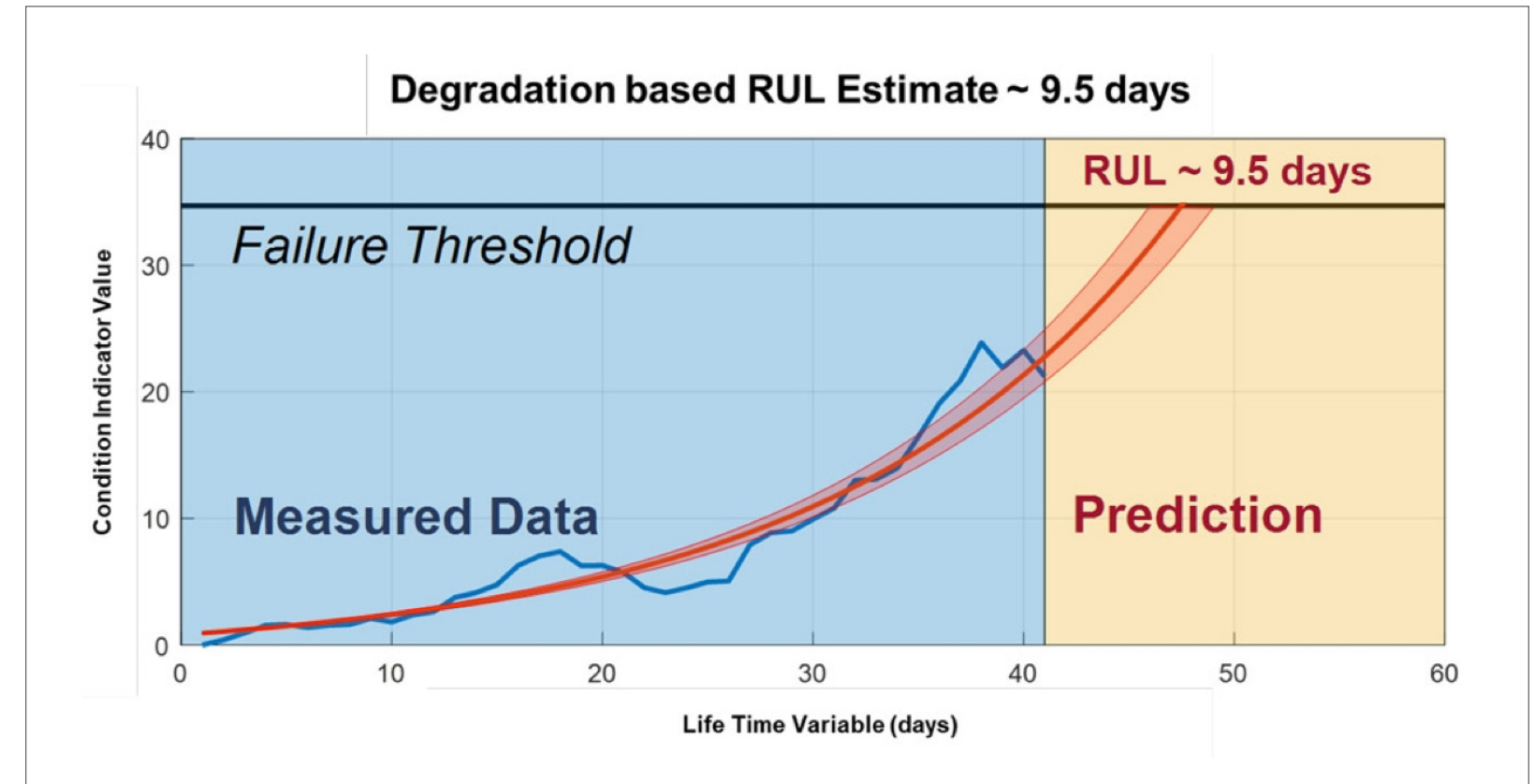
## *with Degradation Models*

Sometimes the only data you have is on prescribed threshold values—for example, the temperature of a liquid in a pump cannot exceed 160°F (71°C) and the pressure must be under 2200 psi (155 bar). With this kind of information, you can fit time series models to condition indicators extracted from sensor data such as temperature and pressure, which rise or fall over time.

These degradation models estimate RUL by predicting when the condition indicator will cross the threshold. They can also be used with a fused condition indicator that incorporates information from more than one condition indicator using techniques such as principal component analysis.

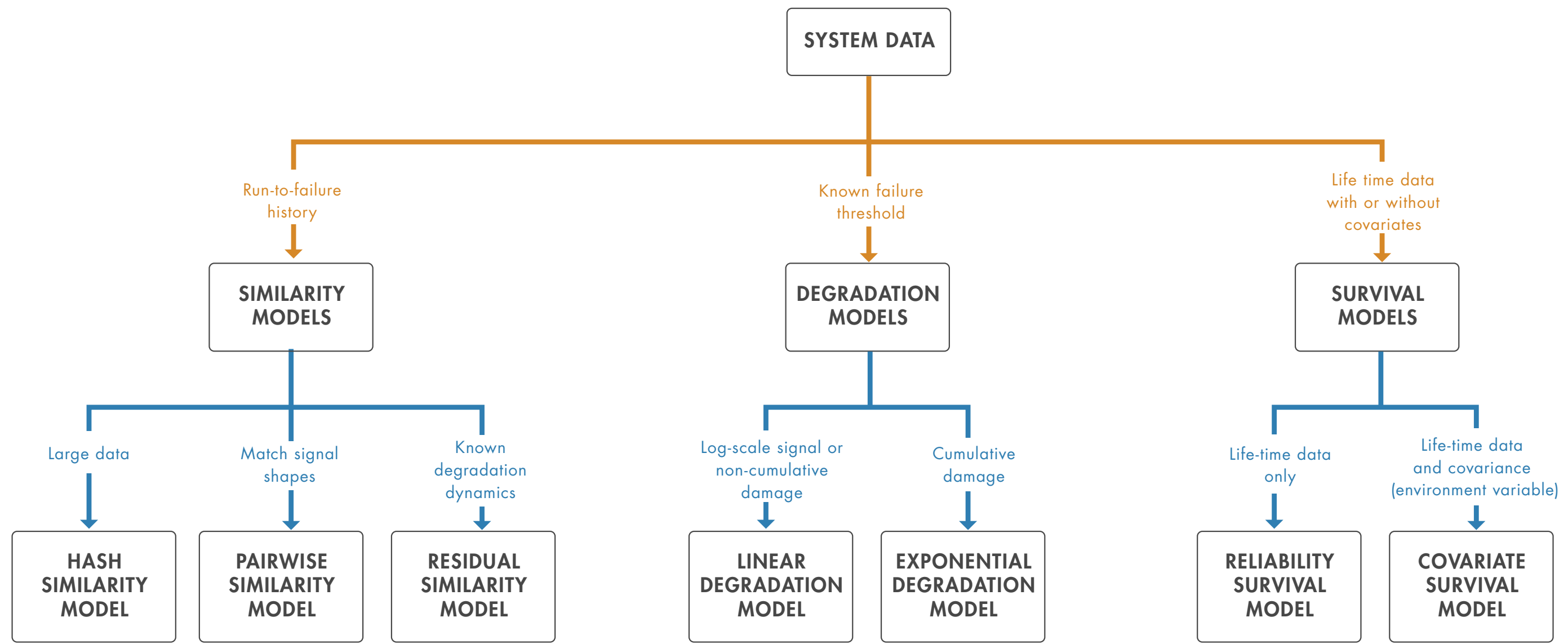
Code example:

[Estimating RUL of High-Speed Bearings Using Exponential Degradation Models](#)



Degradation model for a high-speed bearing. The bearing has an estimated RUL of 9.5 days based on its current condition data (blue) and the exponential degradation model (red) fit to this data.

# Cheat Sheet: Choosing an RUL Estimator



Above are the models supported for RUL estimation in *Predictive Maintenance Toolbox*.

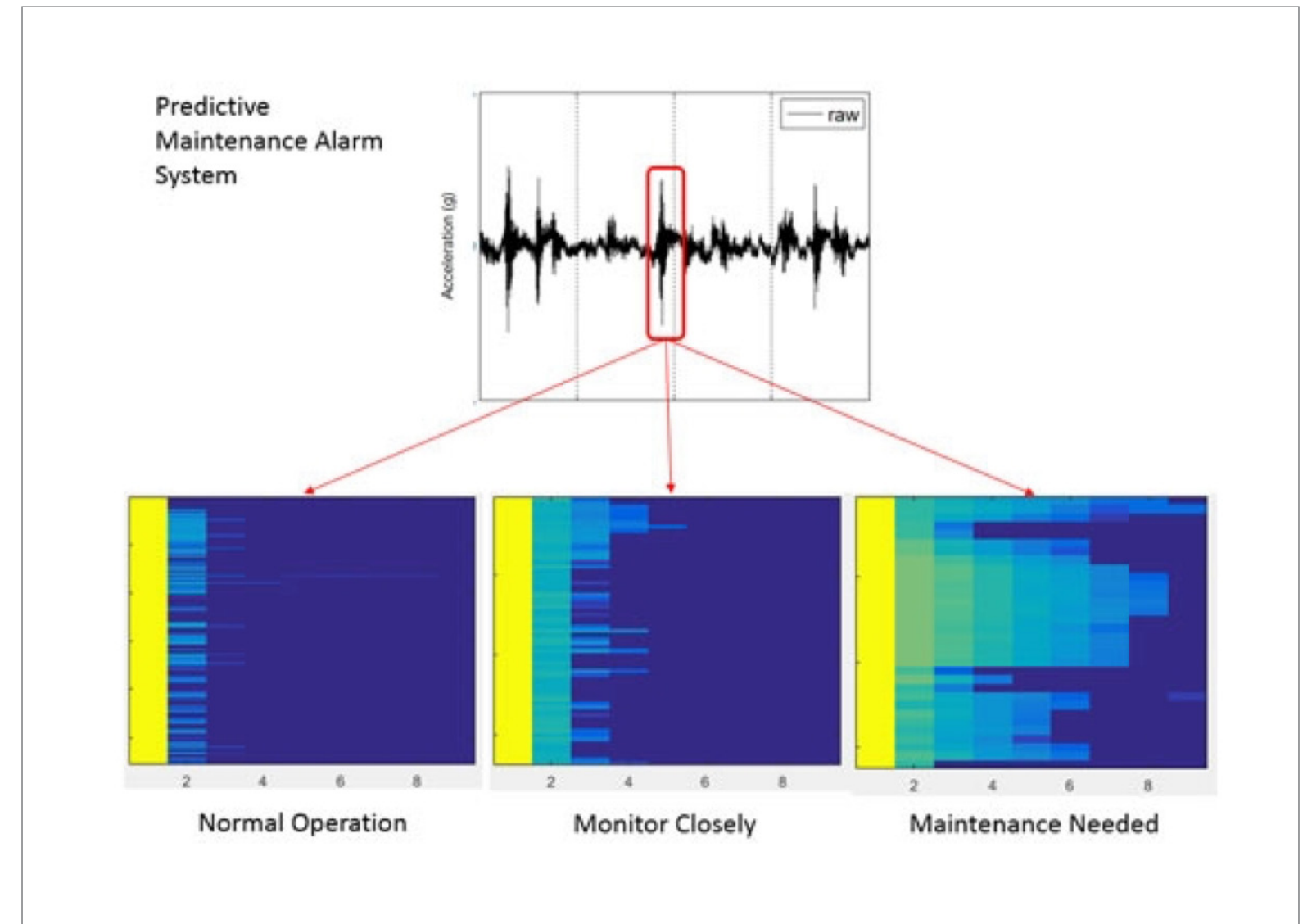
# What's Next?

Once you have reliable estimates for RUL, you can integrate them into dashboards used by operators or incorporate them into alarm systems monitored by maintenance teams.

Teams can then respond to changes in equipment health as quickly as possible, and without affecting operations.

*“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 ([read more](#))



*Predictive maintenance alarm system for Baker Hughes gas and oil extraction equipment.*



# Learn More

Learn more about using MATLAB for predictive maintenance.

[\*Overcoming Four Common Obstacles to Predictive Maintenance with MATLAB and Simulink\*](#) (White Paper)

[\*MATLAB and Simulink for Predictive Maintenance\*](#)  
(Overview)

[\*Predictive Maintenance Software\*](#) (Free Trial)