

Developing Prognostics Algorithms: Data-Based and Model-Based Approaches

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MathWorks Automotive Conference

What is Prognostics?

Prognostics

From Wikipedia, the free encyclopedia

This article is about the engineering discipline. For the medical term, see [prognosis](#).

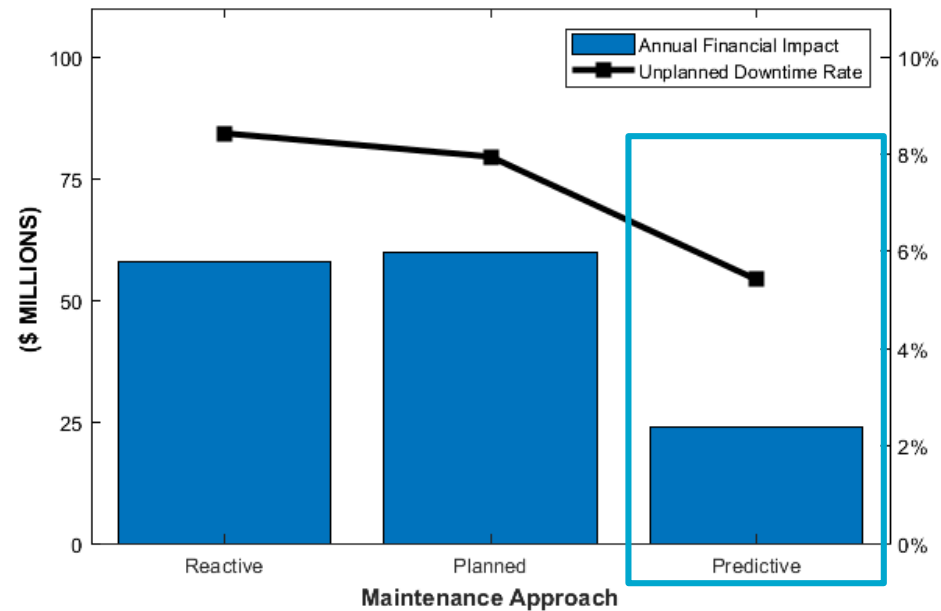
Prognostics is an engineering discipline focused on predicting the time at which a system or a component^[1] will no longer perform its intended function.^[2] This lack of performance is most often a failure beyond which the system can no longer be used to meet desired performance. The predicted time then becomes the **remaining useful life (RUL)**, which is an important concept in decision making for contingency mitigation. Prognostics predicts the future

....

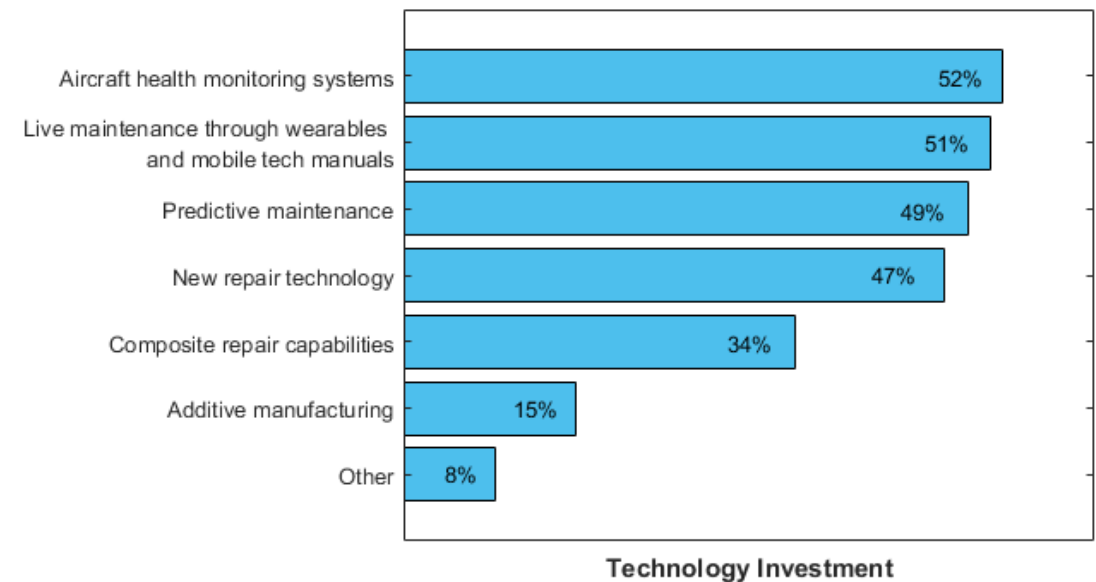
conditions.^[3] The science of prognostics is based on the analysis of failure modes, detection of early signs of wear and aging, and fault conditions. An effective prognostics solution is implemented when there is sound knowledge of the failure mechanisms that are likely to cause the degradations leading to eventual failures in the system. It is therefore necessary to have initial

Why Prognostics?

- Improved operating efficiency
- New revenue streams
- Competitive differentiator

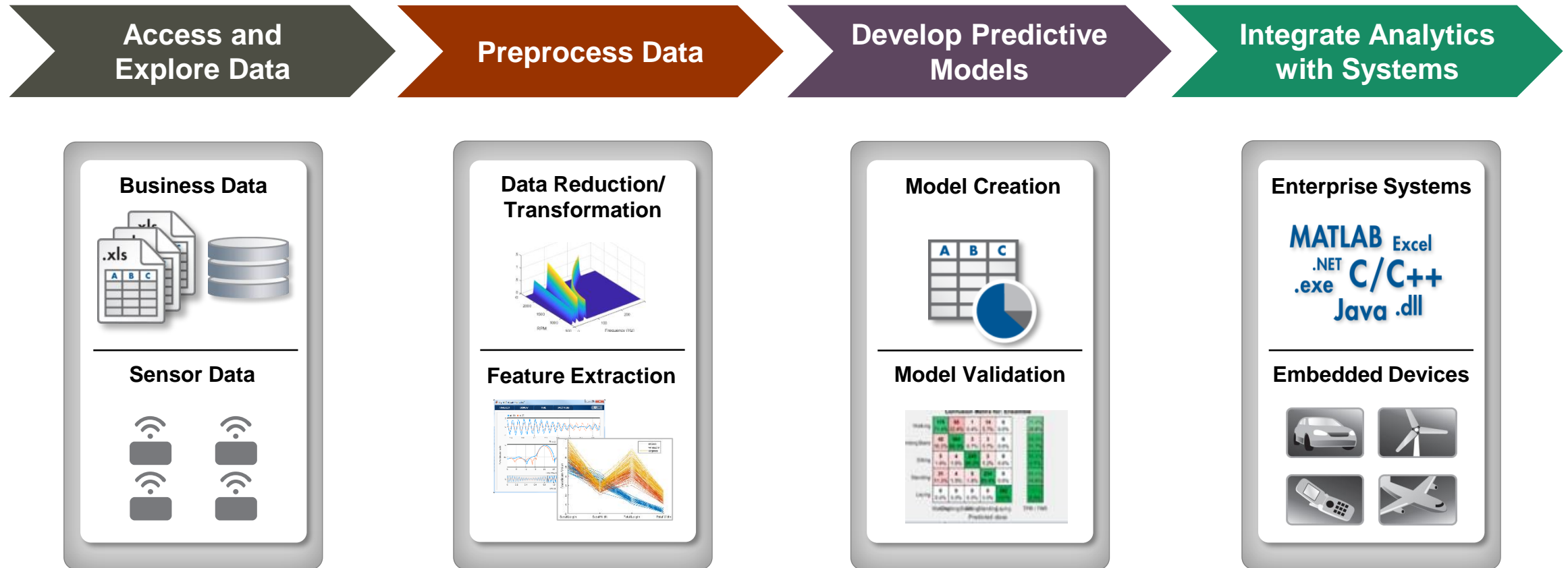


Source: GE Oil & Gas



Source: Oliver Wyman 2015 MRO Survey

How does it work? Prognostics Algorithm Workflow

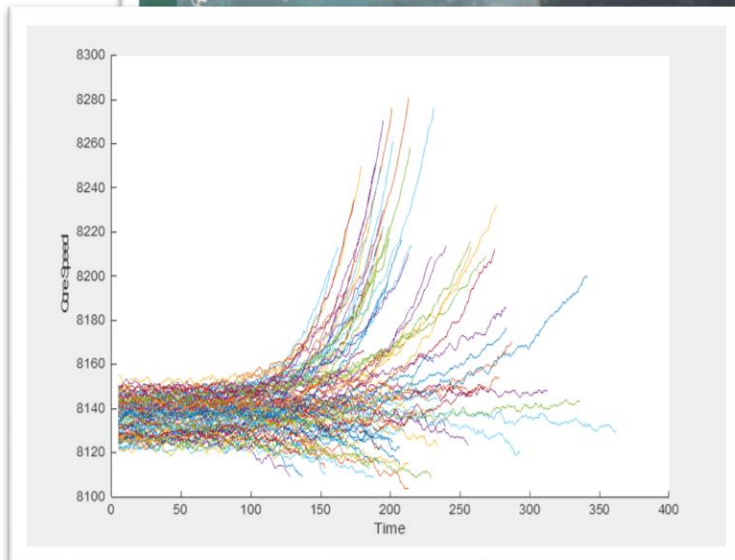
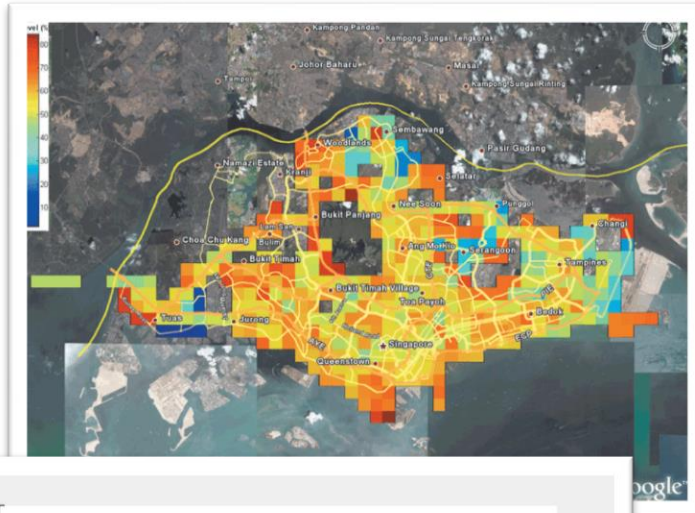


Challenges for Prognostics Development

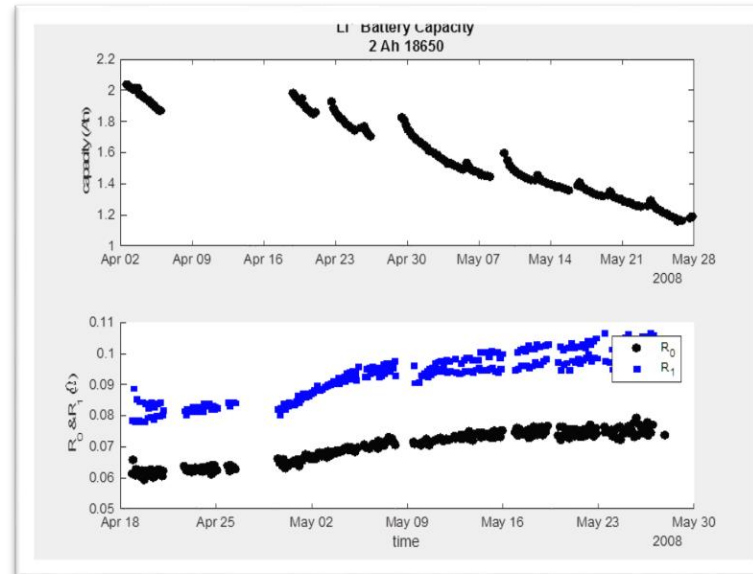
- How long will it take to collect fault data?
- How expensive is it to collect?
- How complex is the system?

Sources of Data for Prognostics Development

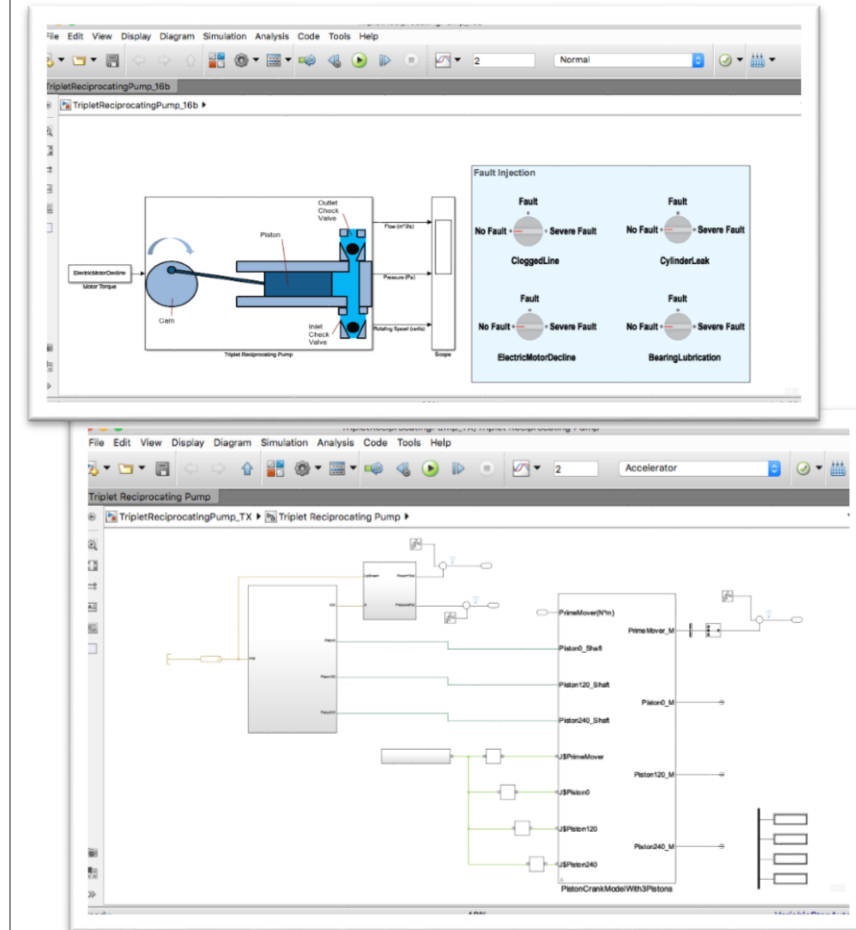
Fleet



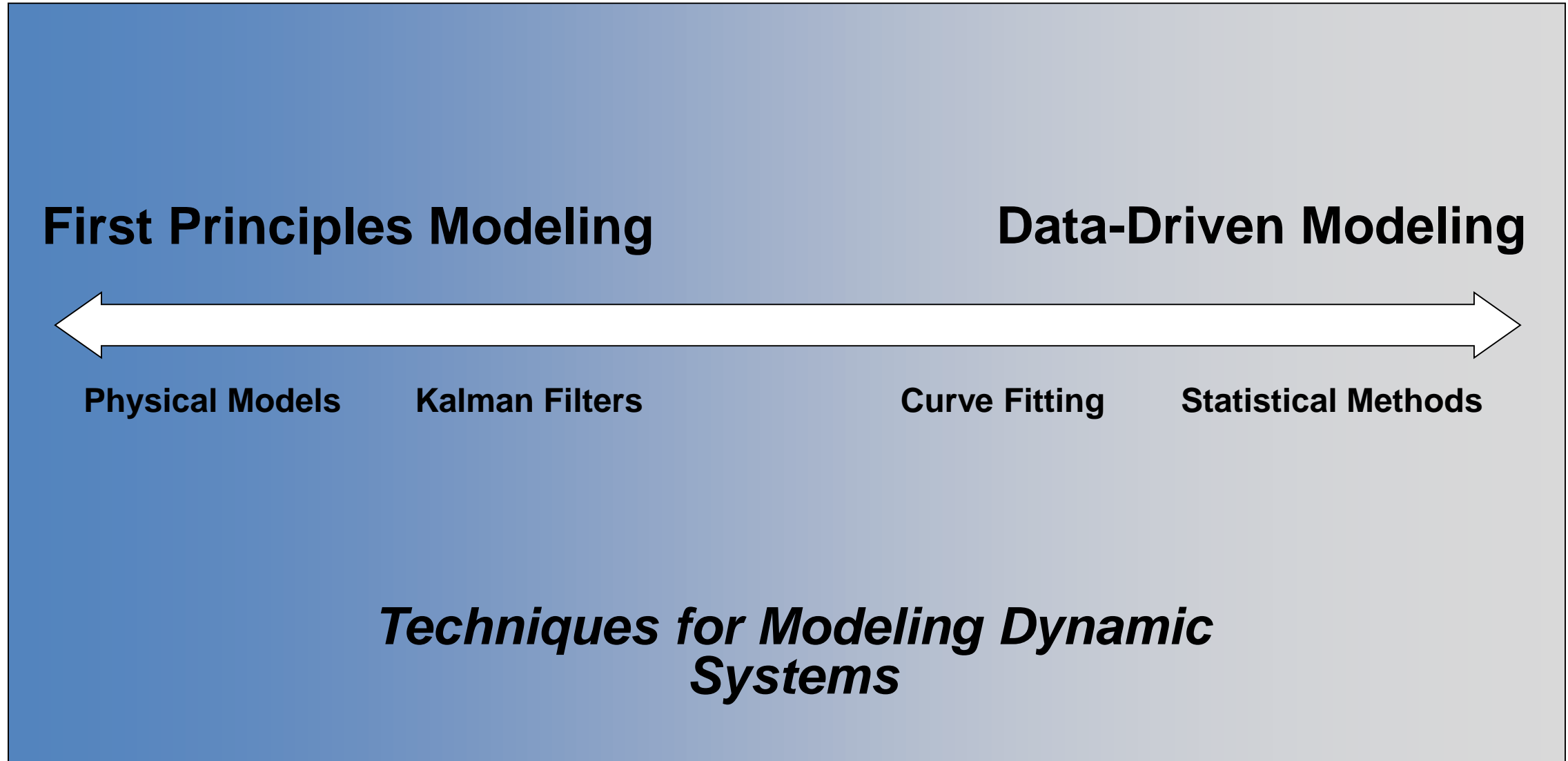
Experiments



Simulation



Spectrum of Approaches for Prognostics Algorithms



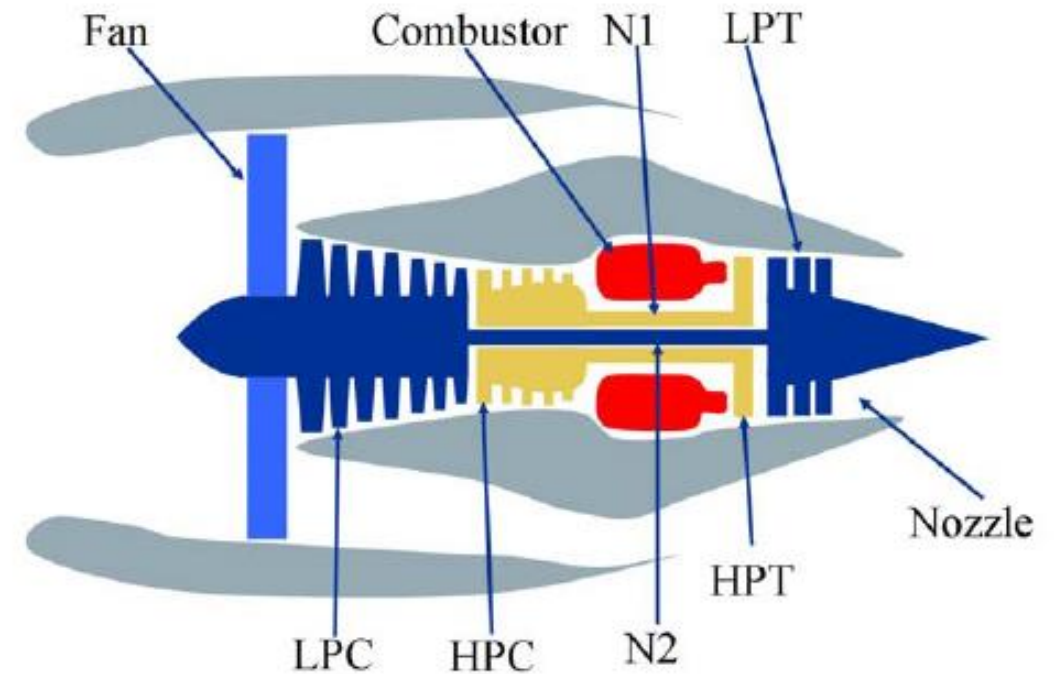
Examples

1. Data-based prognostics using machine learning
2. Fault injection and failure analysis using simulation

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Example 1: Data-based Prognostics with Machine Learning



Data provided by NASA PCoE

<http://ti.arc.nasa.gov/tech/dash/pcoe/prognostic-data-repository/>

Different Types of Learning

Type of Learning

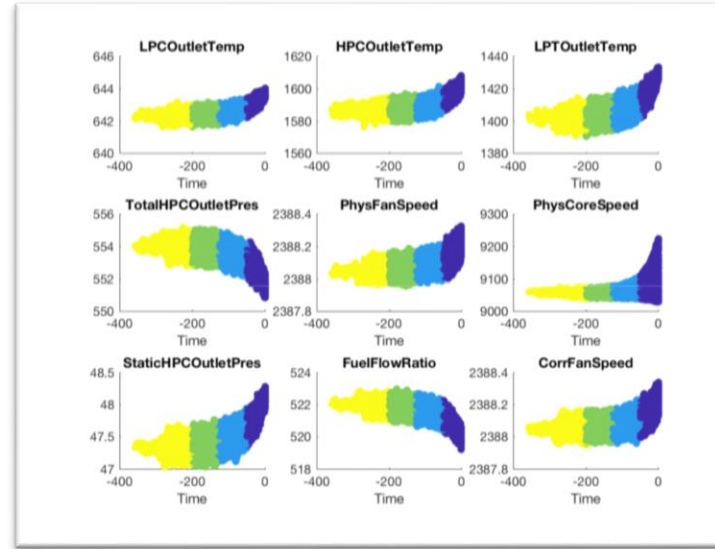
Machine Learning

Supervised Learning

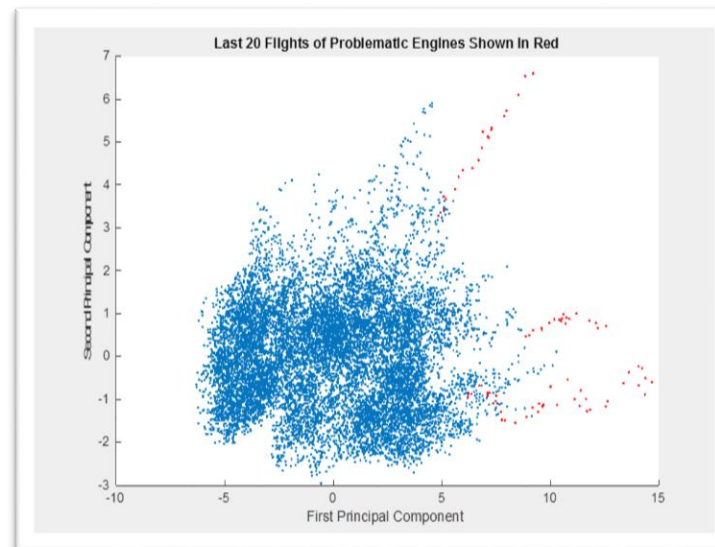
Develop **predictive model** based on both **input and output data**

Unsupervised Learning

Discover an **internal representation** from **input data only**

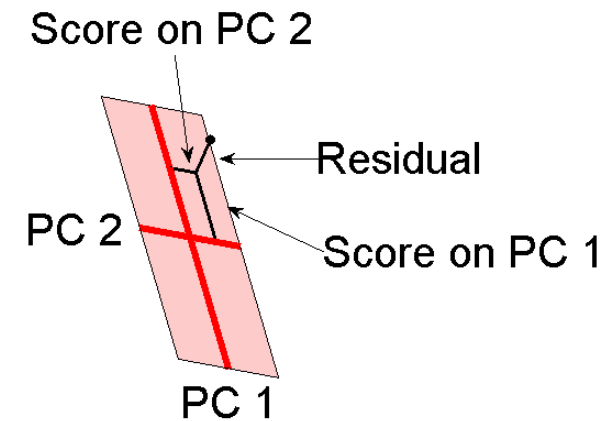
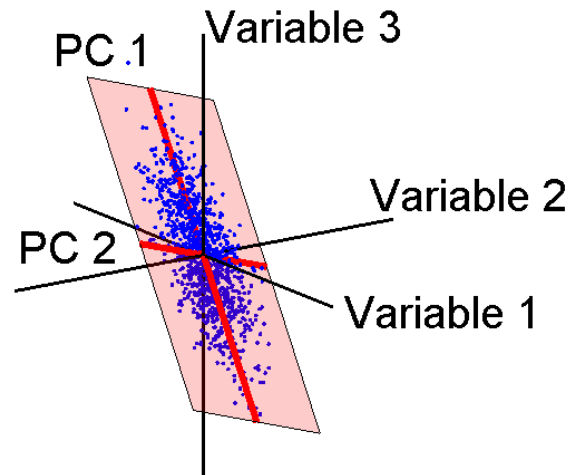
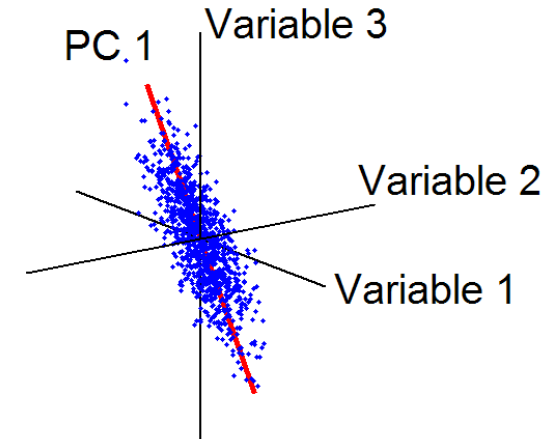
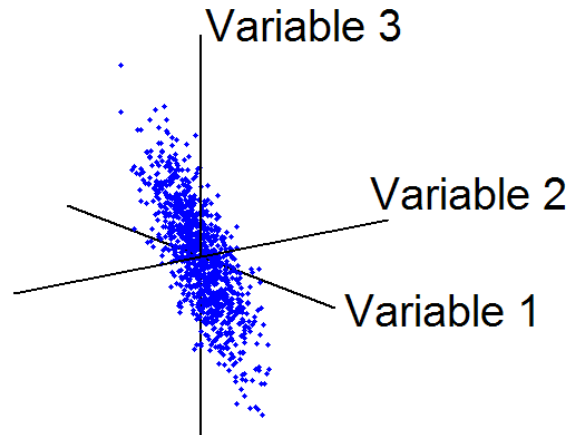


Predicting Failures

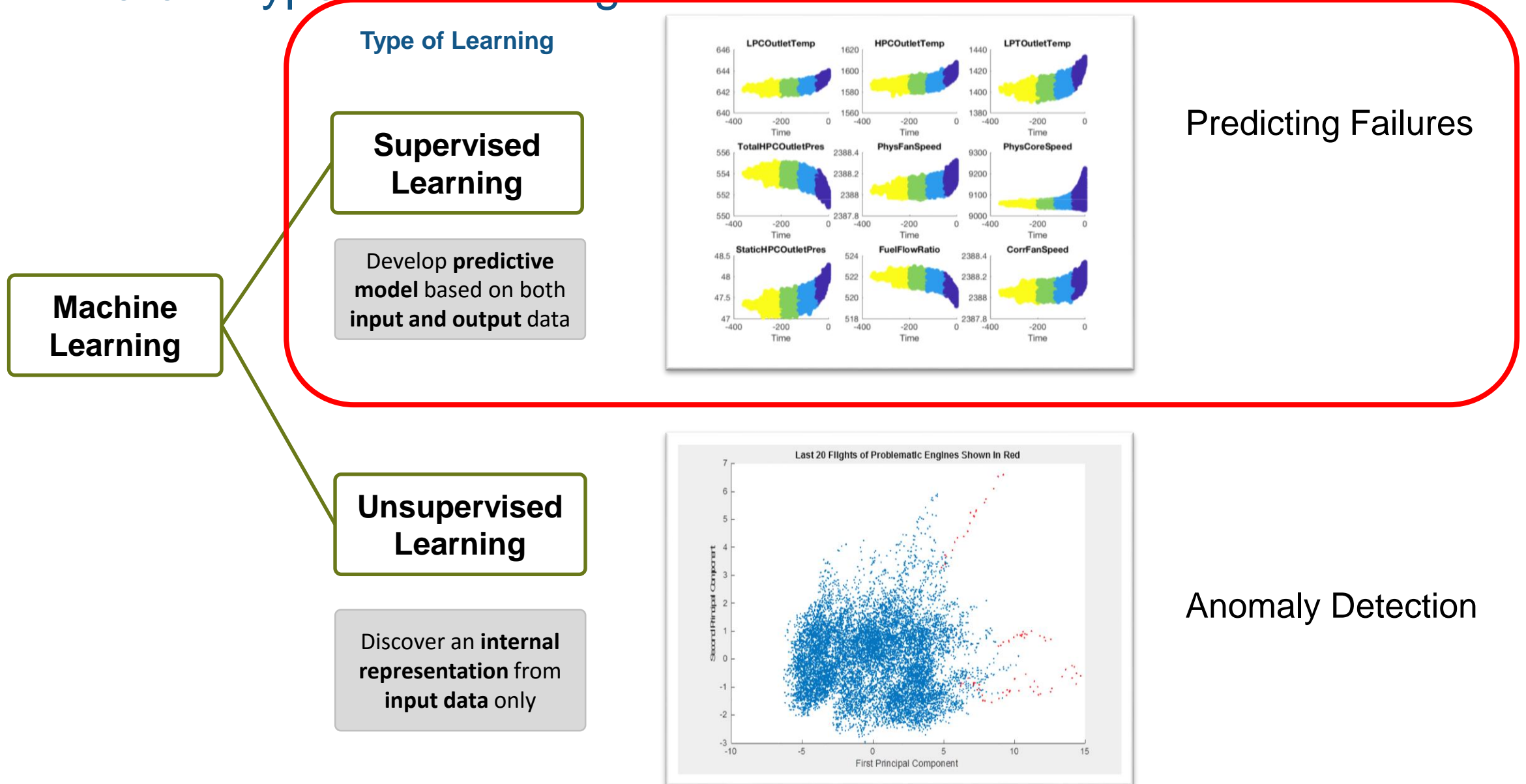


Anomaly Detection

Principal Components Analysis – what is it doing?

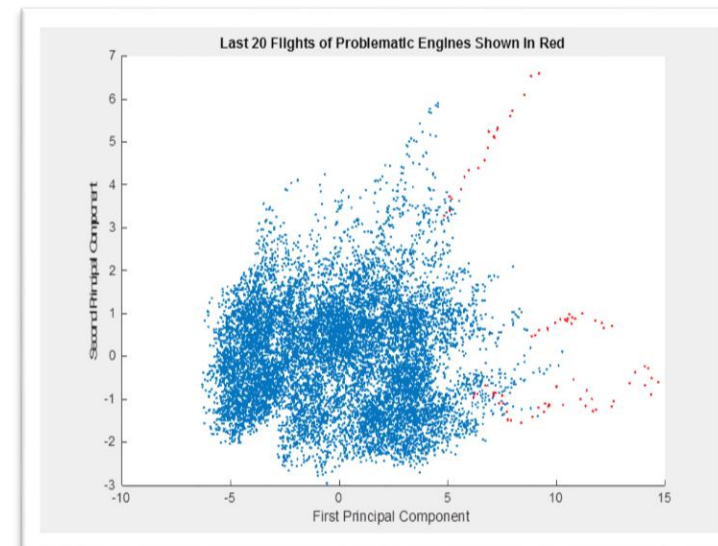
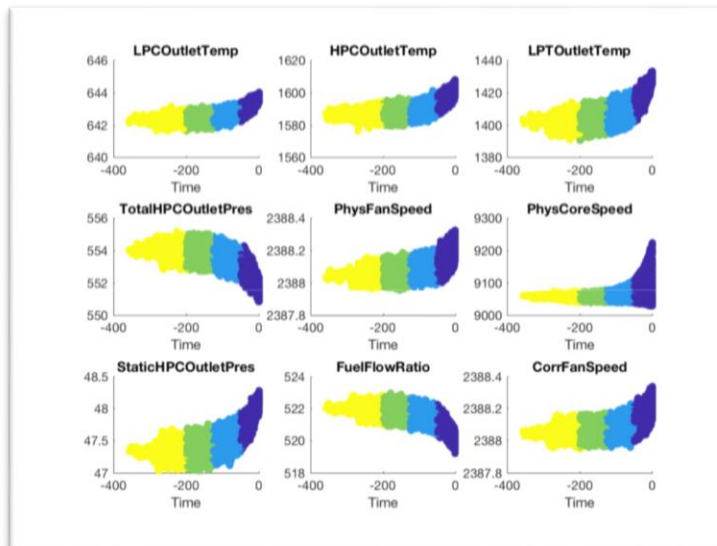


Different Types of Learning



Data-based Prognostics with Machine Learning - Takeaways

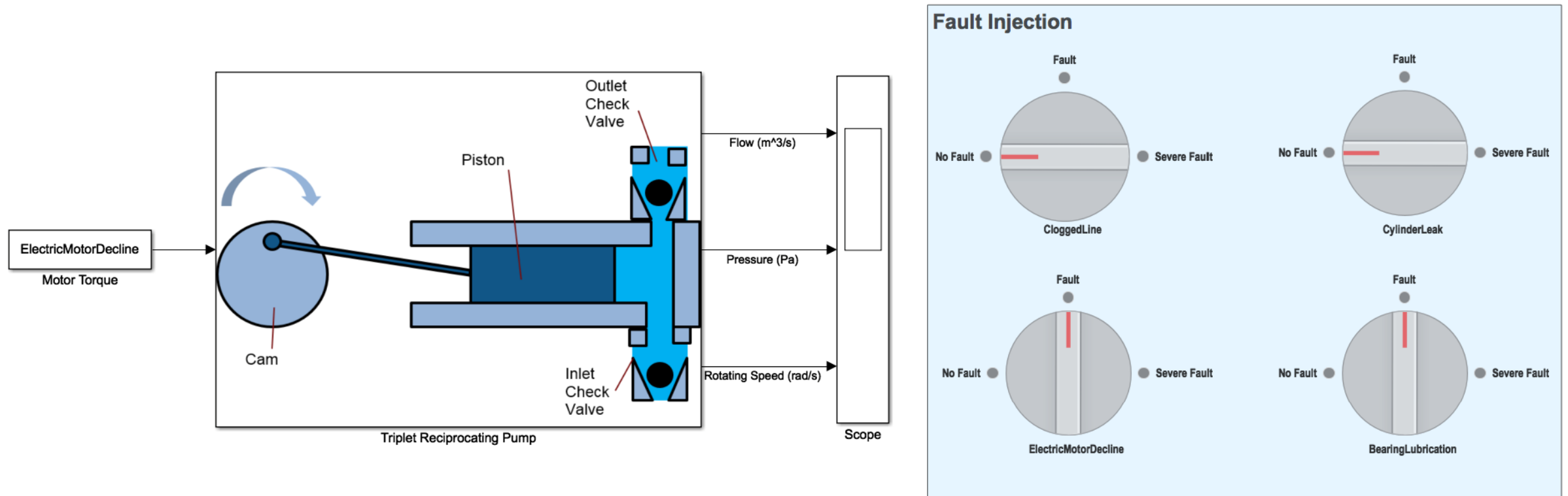
- Use machine learning to identify outliers and build predictive models
- Many choices for algorithms, apps make it easy to compare options
- Workflow-focused tools help you fine-tune the model to your particular data



Examples

1. Data-based prognostics using machine learning
2. Fault injection and failure analysis using simulation

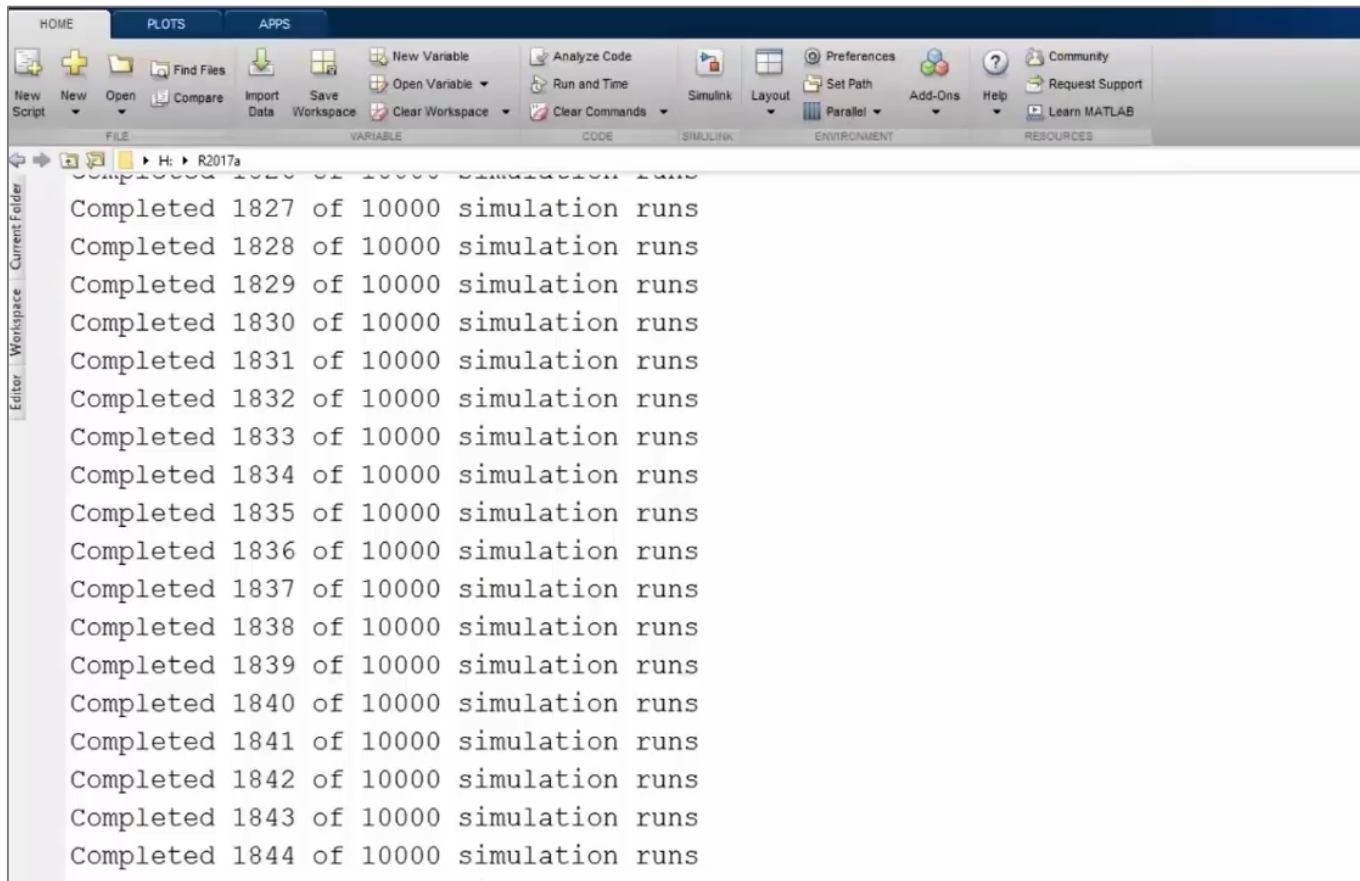
Example 2: Fault injection and failure analysis using simulation



FrequencyAnalysisButton

Double-click here to turn
the Mechanics Explorer
ON

Run multiple parallel simulations from the `parsim` command



The image shows the MATLAB R2017a interface. The command window displays the output of the `parsim` command, showing a list of completed simulation runs. The output is as follows:

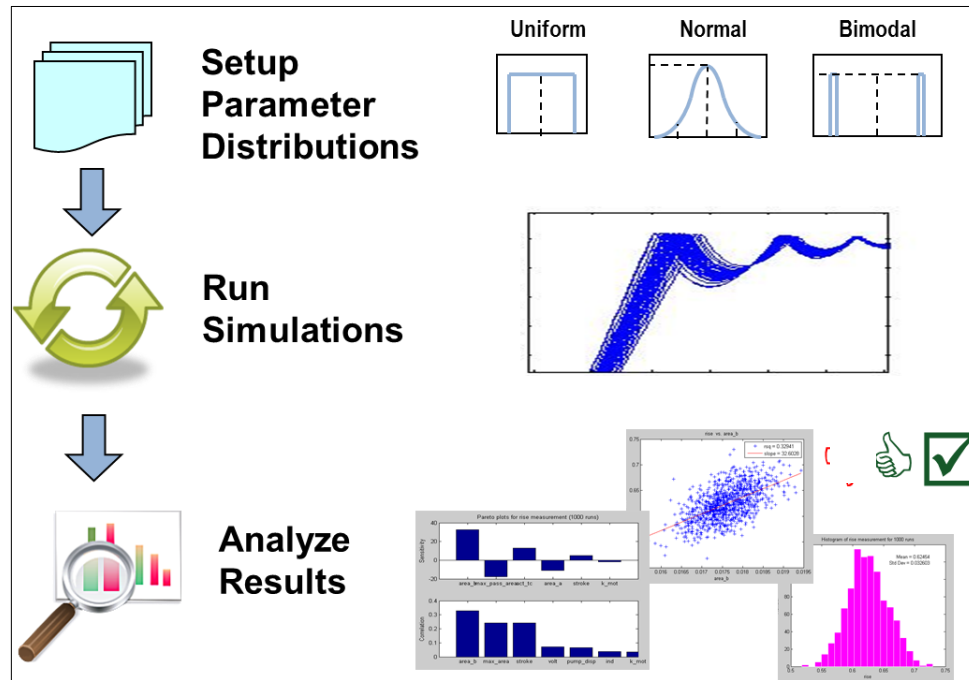
```
Completed 1827 of 10000 simulation runs  
Completed 1828 of 10000 simulation runs  
Completed 1829 of 10000 simulation runs  
Completed 1830 of 10000 simulation runs  
Completed 1831 of 10000 simulation runs  
Completed 1832 of 10000 simulation runs  
Completed 1833 of 10000 simulation runs  
Completed 1834 of 10000 simulation runs  
Completed 1835 of 10000 simulation runs  
Completed 1836 of 10000 simulation runs  
Completed 1837 of 10000 simulation runs  
Completed 1838 of 10000 simulation runs  
Completed 1839 of 10000 simulation runs  
Completed 1840 of 10000 simulation runs  
Completed 1841 of 10000 simulation runs  
Completed 1842 of 10000 simulation runs  
Completed 1843 of 10000 simulation runs  
Completed 1844 of 10000 simulation runs
```

- Speed up simulations and simplify workflow
- Simplifies large simulation runs

Leverage Parallel Computing with Simulink

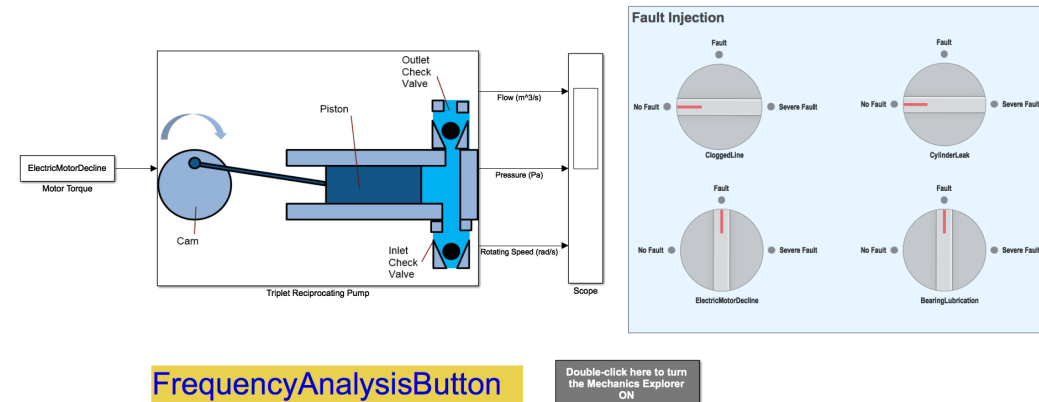
Reduce the total amount of time it takes to...

Run multiple independent simulations (E.g.
Parameter sweeps, Monte Carlo Analysis)

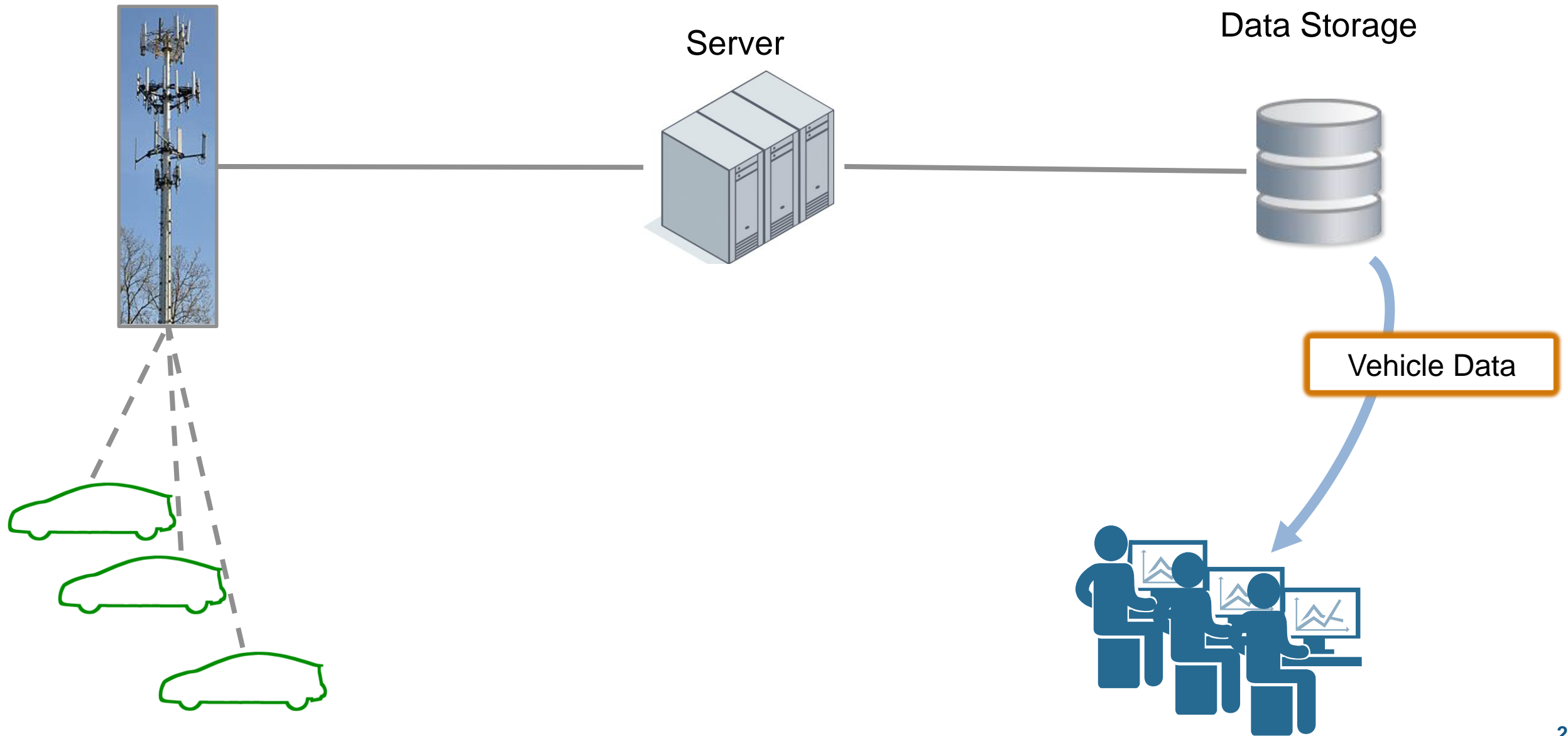


Fault injection and failure analysis – Takeaways

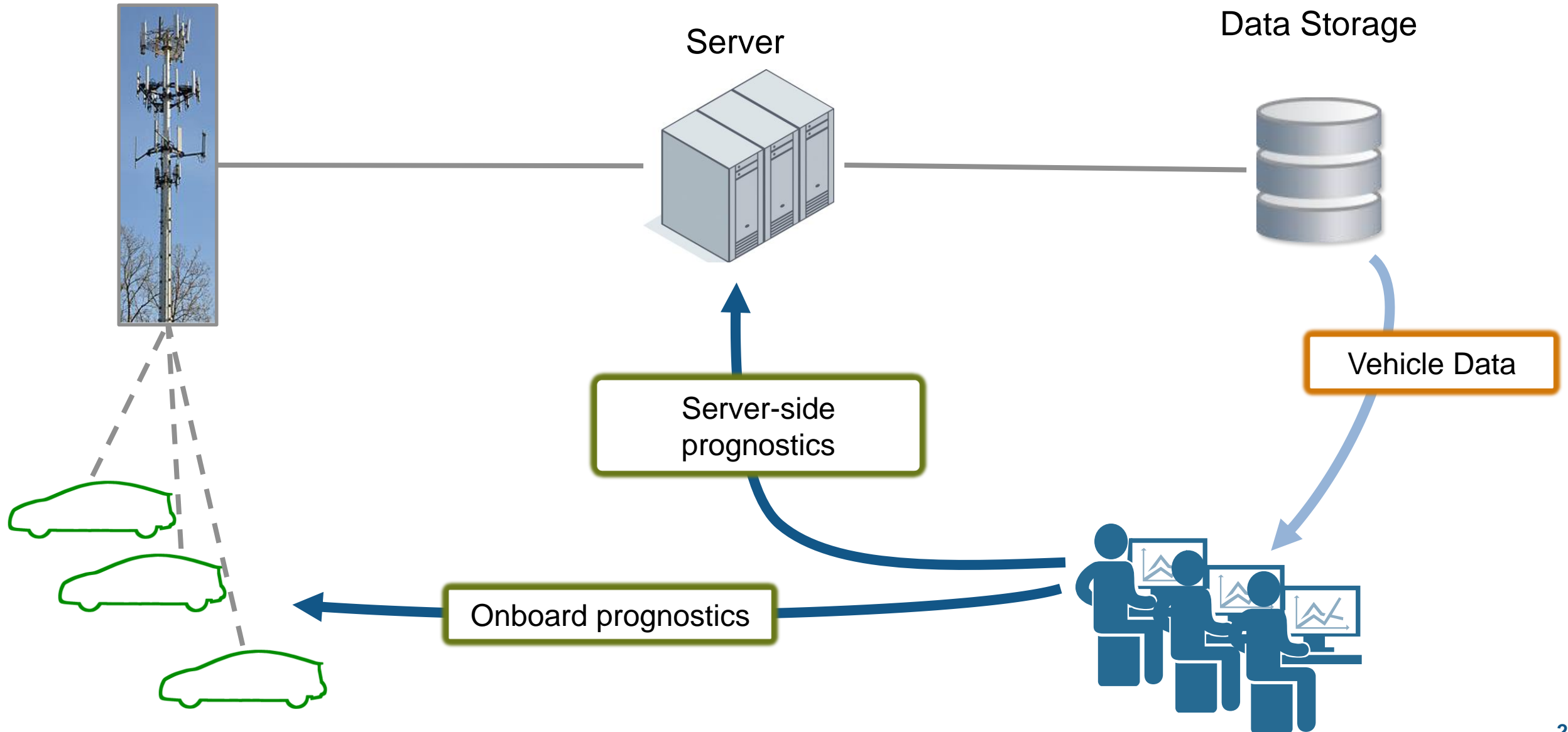
- Use simulation when measured data is not available
- Run what-if analyses to explore scenarios that are difficult to recreate
- Comparing field data to simulation data can help diagnose cause-of-failure



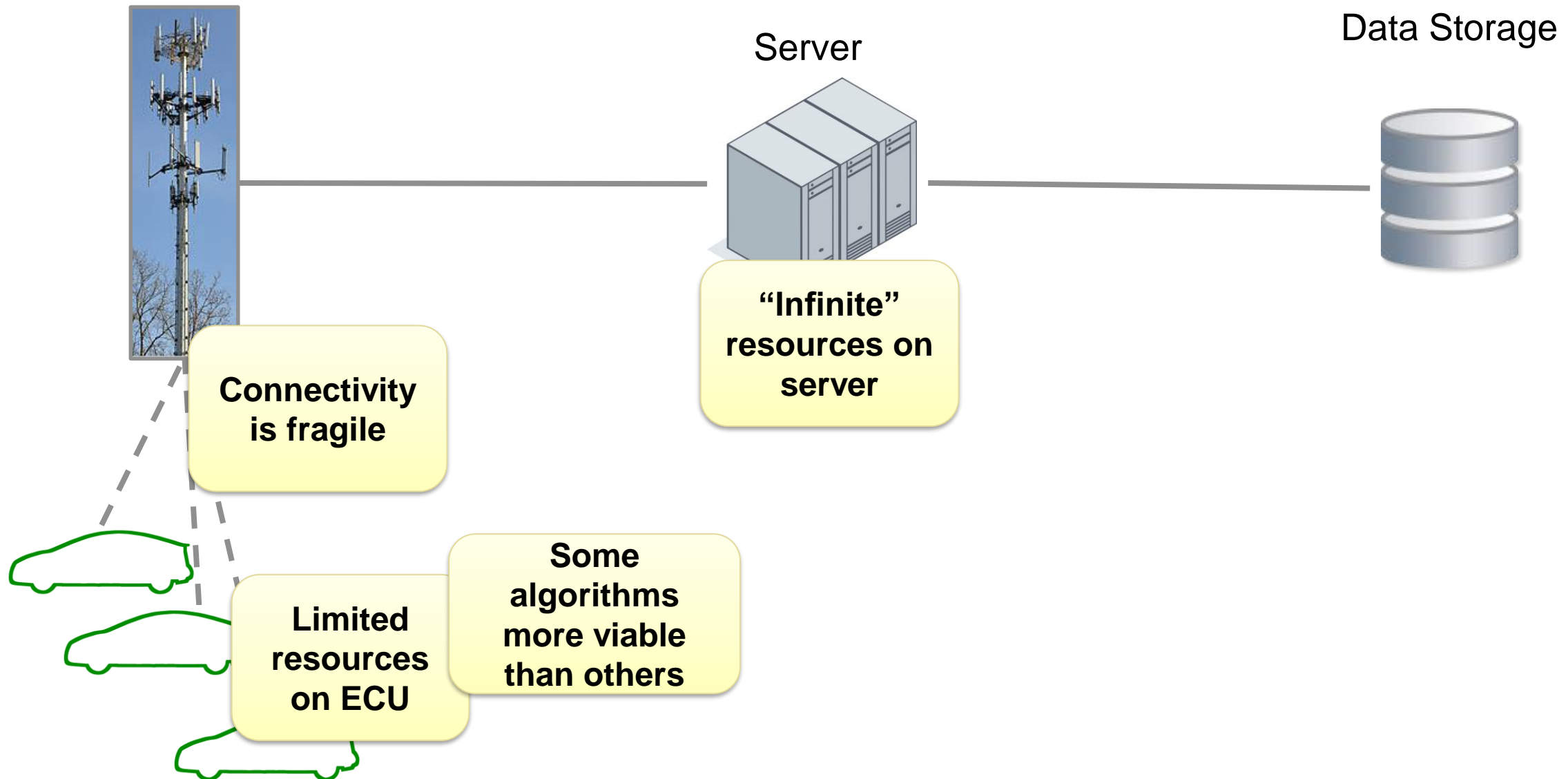
Fleet Data for Prognostics Development



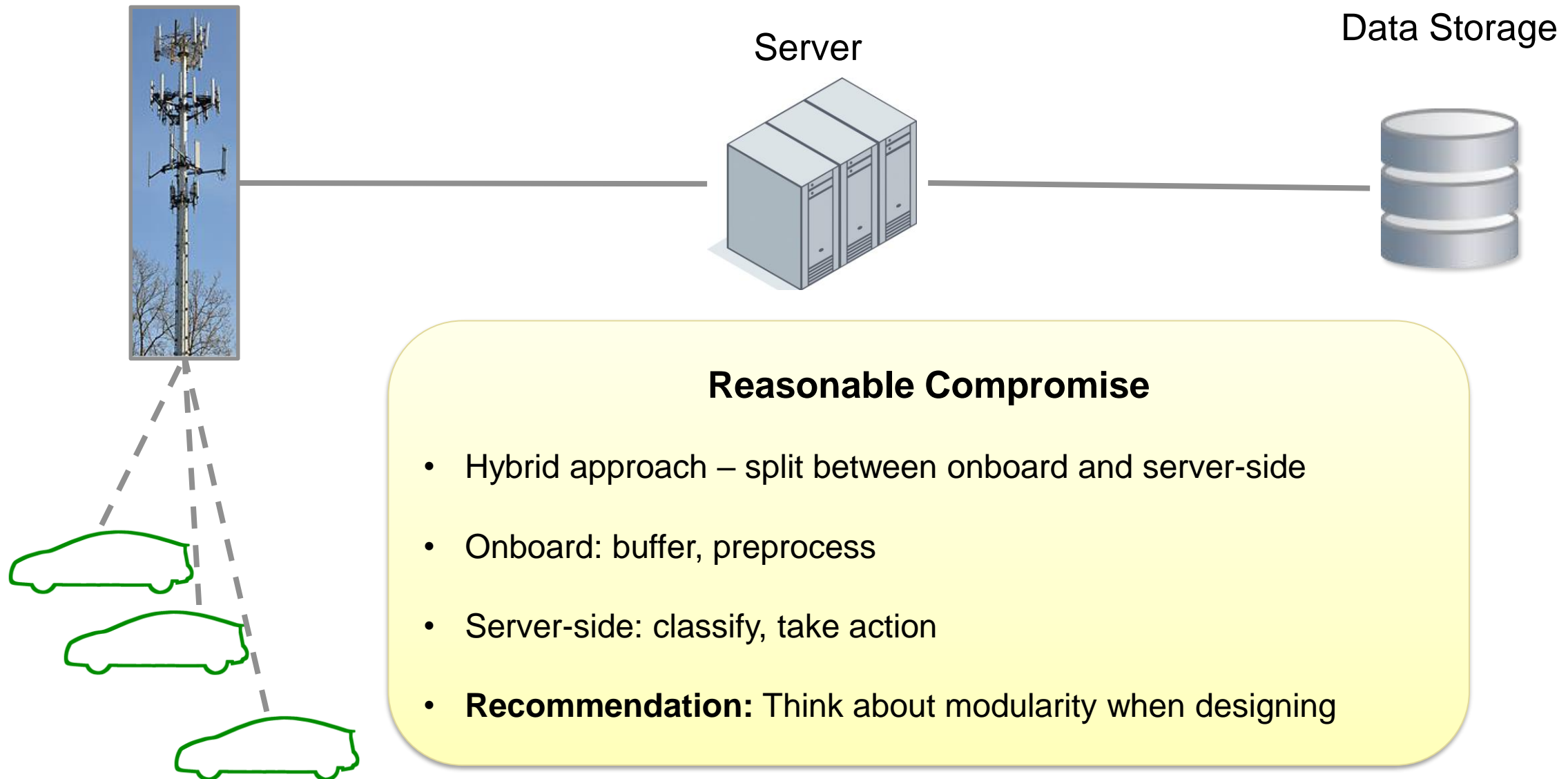
Deploying Prognostics Algorithms



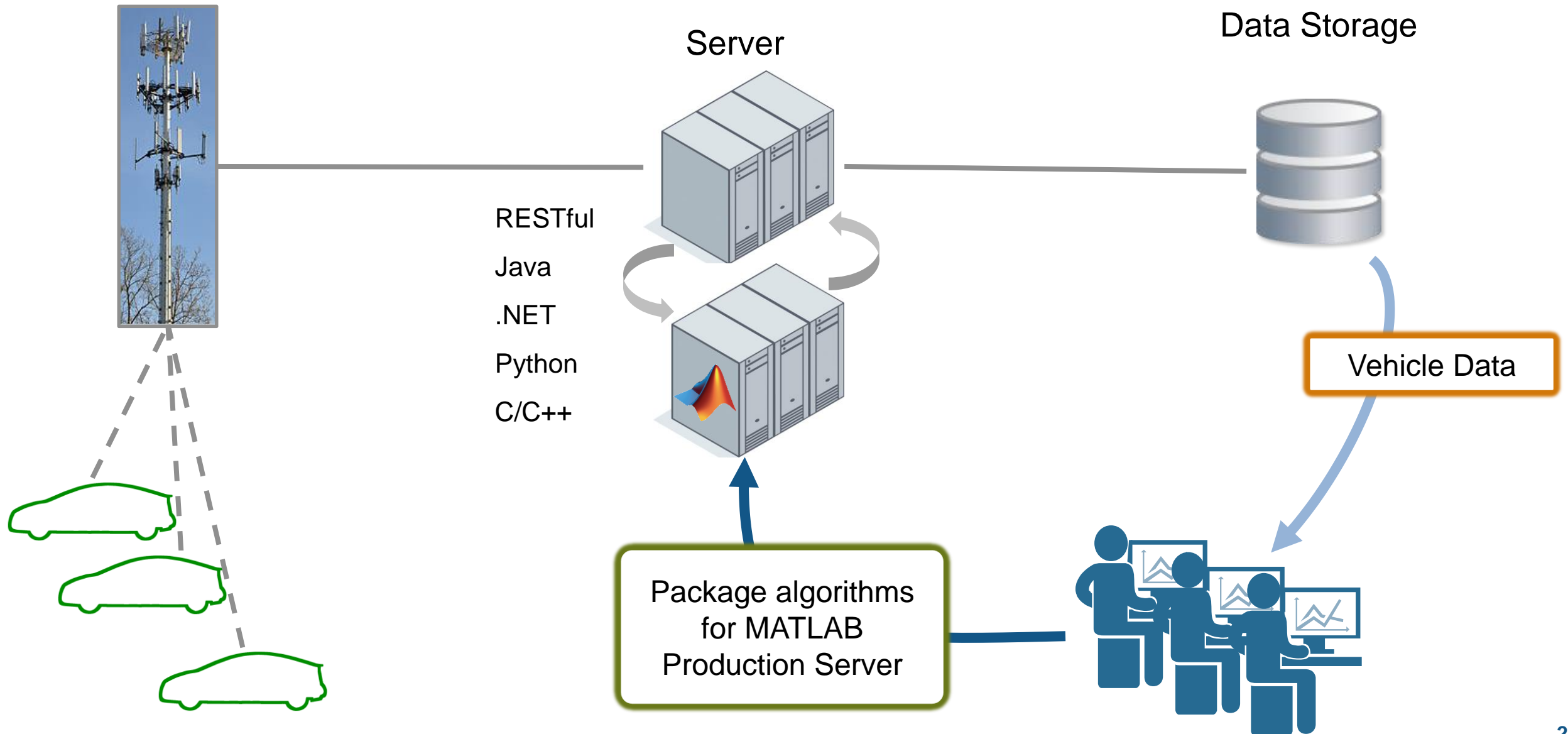
Considerations for System Architecture



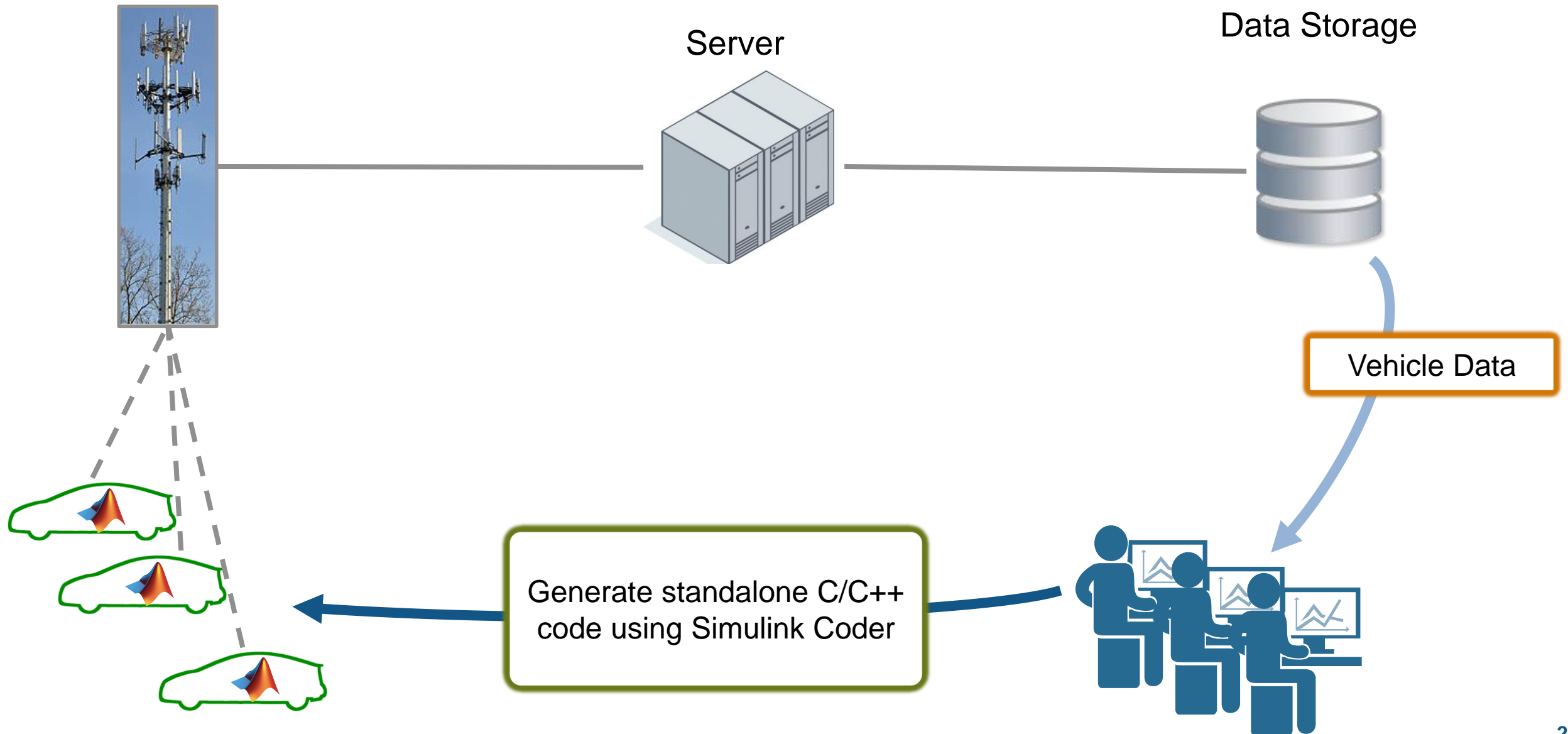
Considerations for System Architecture



Server-side Prognostics

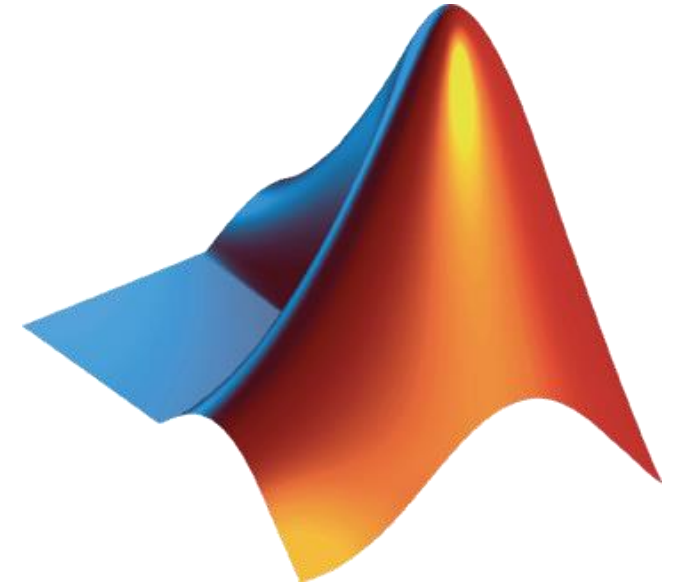


Onboard Prognostics



Key Takeaways

- No “one-size-fits-all” approach to prognostics.
- Prognostics system architecture is evolving.
- MATLAB and Simulink provide a platform for developing prognostics algorithms.



Learn More

mathworks.com/machine-learning

Machine Learning with MATLAB

Overview | Examples

Machine Learning with MATLAB Webinar

Learn how to get started using machine learning tools to detect patterns and build predictive models from your data sets.

Watch video

Choosing the Best Classification Model and Avoiding Overfitting

Download white paper

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Engineers and data scientists work with large amounts of data in a variety of formats such as sensor, image, video, telemetry, databases, and more. They use machine learning to find patterns in data and to build models that predict future outcomes based on historical data. With MATLAB®, you have immediate access to prebuilt functions, extensive toolboxes, and specialized apps for **classification**, **regression**, and **clustering**. You can:

- Compare approaches such as logistic regression, classification trees, support vector machines, ensemble methods, and **deep learning**.
- Use model refinement and reduction techniques to create an accurate model that best captures the predictive power of your data.
- Integrate machine learning models into enterprise systems, clusters, and clouds, and target models to real-time embedded hardware.

Machine Learning with MATLAB

Machine Learning with MATLAB Overview

Deep Learning in 11 Lines of MATLAB Code

Deep Learning with MATLAB

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Why Use MATLAB?

Roy Lurie, VP of Engineering Products, underscores the convenience and scalability of MATLAB.

Watch video

MATLAB® provides a single, high-performance environment for working with big data. MATLAB is:

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Predictive Analytics with MATLAB

Use machine learning with big data for engineering-driven analytics.

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Advanced Crash Detection: The Road from Deployment to Production

Watch video (4:46)

Example: Model-based approach

