Predictive Maintenance
Prognostics and Health Monitoring

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Condition Monitoring

Prognostics

Retail Analytics

Fleet Analytics

Operational Analytics

Process Analytics

Risk Analysis

Health Monitoring

Supply Chain

Asset Analytics

Healthcare Analytics

Why perform predictive maintenance?

- Example: faulty braking system leads to windmill disaster
  - https://youtu.be/-YJuFvjtM0s?t=39s
- Wind turbines cost millions of dollars
- Failures can be dangerous
- Maintenance also very expensive and dangerous

Types of Maintenance

- Reactive – Do maintenance once there's a problem
  - Example: replace car battery when it has a problem
  - Problem: unexpected failures can be expensive and potentially dangerous
- Scheduled – Do maintenance at a regular rate
  - Example: change car's oil every 5,000 miles
  - Problem: unnecessary maintenance can be wasteful; may not eliminate all failures
- Predictive – Forecast when problems will arise
  - Example: certain GM car models forecast problems with the battery, fuel pump, and starter motor
  - Problem: difficult to make accurate forecasts for complex equipment

Benefits of Predictive Maintenance

Increase “up time” and safety	**Reliability**
Minimize maintenance costs	**Cost of Ownership**
Optimize supply chain	**Reputation**

Aircraft Maintenance

IATA

AIRLINE MAIN
EXECUTIVE

An Exclusive
by IA

MCTF
December 2015

PUBLIC

Global Picture

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for 2014. The ind
profit of $19.9 bil

In 2014, the worl
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billion on MRO, re

DEVELOPING TRENDS AND TECHNOLOGIES IN MAINTENANCE

- Aircraft health monitoring systems and big data: e-aircraft are constantly monitoring and transmitting faults and warnings for a more dynamic planning and check scheduling
- New technologies: mobile devices, wearables (e.g. Google Glass) and real-time video transmission for front-line support, e-logbooks for paperless operations, drones and/or sensors for remote inspections
- Predictive maintenance is estimated to increase aircraft availability by up to 35%
- Composite repair capabilities
- Additive manufacturing (3-D printing) is continuously growing, reducing lead times, increasing part availability, optimizing parts and saving weight.

These innovations are estimated to decrease MRO spending by 15 to 20% but first, the market needs to innovate with a clear vision and strategy.

It is critical to identify opportunities and isolate the most promising ones, then develop an innovation process to transform these opportunities into pilot projects and market roll-outs.

Sources:
IATA Economics (June 2015)
IATA Airline Cost Management Group (August 2015)
ICF International Global MRO Forecast (Jan 2015)

Global Picture 15

Report Link

What Does Success Look Like?

Safran

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  - – Limit secondary damage

Introduction to SAMANTA

→ **What is SAMANTA ?**

- SAMANTA (Snecma Algorithm Maturation ANd
environment for **Design, Development** and **Ma**
items

→ **Why develop this platform ?**

- To enable engineers to quickly and easily lay o
knowledge in mathematics or computer science
- To facilitate exchanges between algorithm desi
common and consistent operations
- To capitalize on algorithms
- To create a complete interface between algoritl
documents

→ **Why with MATLAB?**

- To quickly and easily create a platform giving tl
through written code or through connecting blo

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Engine systems monitored

Hydraulic system
- Debris
- Smart filter

Performance
- Modular analysis
- Thermodynamic cycle monitoring

General
- Anomaly detection
- Fusion/Decision making
- Fleet cartography

Control system
- Sensors Monitoring
- Actuators Monitoring
- Assisted troubleshooting
- Failure warnings

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SAFRAN Snecma

Conclusion

→ **The SAMANTA platform was created in 2007 and about 160 modules were designed since then**

- Today about 15 engine monitoring algorithms have been developed, tested and matured through this platform and modules
- The next step for Snecma is to compile these algorithms to be able to export them and use them in an operational environment thanks to the MPS

→ **Thirty people are now using this platform in several companies of the SAFRAN Group**

- Snecma, Turbomeca, Safran Engineering Services, Sagem,…
- Among all regular users of the platform, only 1/3 have a computer science background

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SAFRAN Snecma

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MATLAB VIRTUAL CONFERENCE 2015

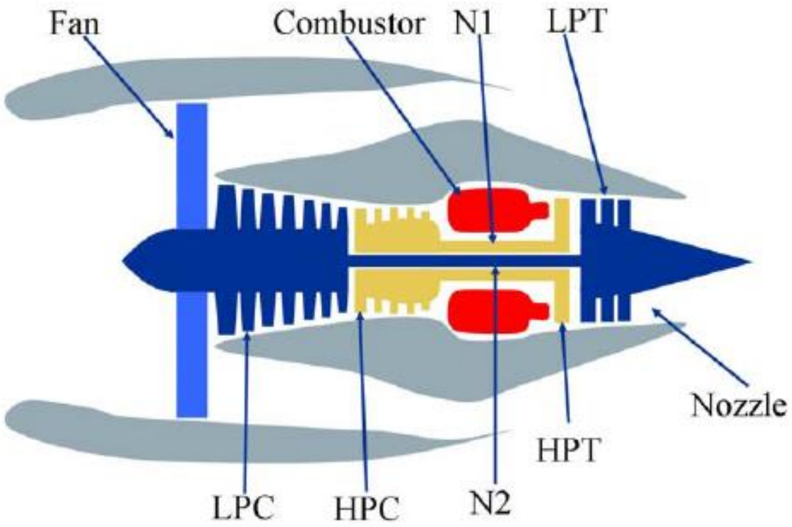
http://www.mathworks.com/company/events/conferences/matlab-virtual-conference/
View Presentation

Predictive Maintenance of Turbofan Engine

Sensor data from 100 engines of the same model

Predict and fix failures before they arise

- Import and analyze historical sensor data
- Train model to predict when failures will occur
- Deploy model to run on live sensor data
- Predict failures in real time



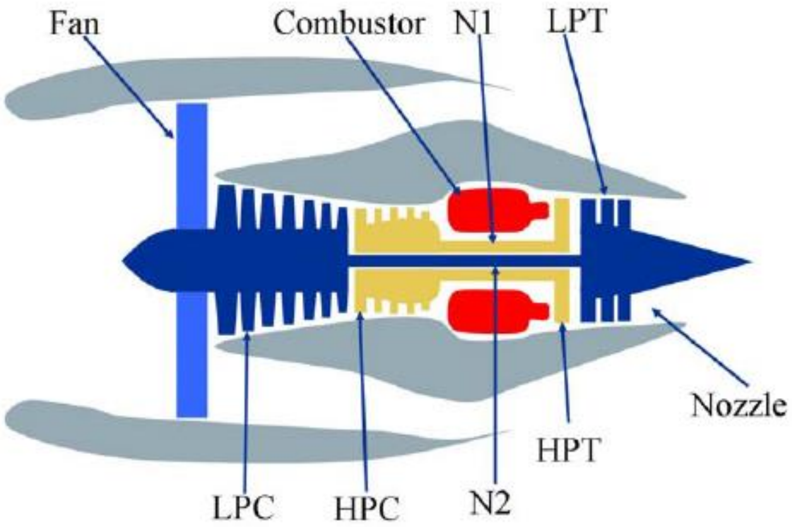
Data provided by NASA PCoE
http://ti.arc.nasa.gov/tech/dash/pcoe/prognostic-data-repository/

Predictive Maintenance of Turbofan Engine

Sensor data from 100 engines of the same model

Scenario 1: No data from failures

- Performing scheduled maintenance
- No failures have occurred
- Maintenance crews tell us most engines could run for longer
- Can we be smarter about how to schedule maintenance **without** knowing what failure looks like?



Data provided by NASA PCoE
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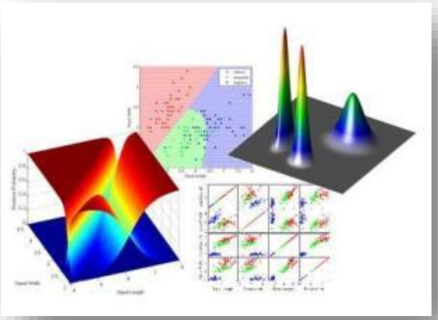
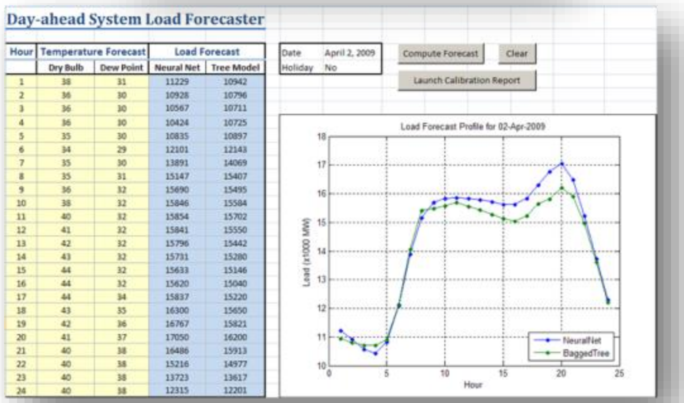
Machine Learning

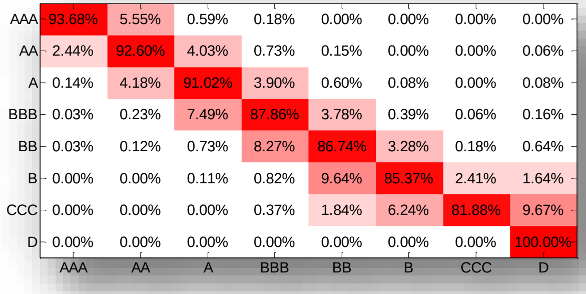
Characteristics and Examples

- Characteristics
  - Too many variables
  - System too complex to know the governing equation
    (e.g., black-box modeling)

- Examples
  - Pattern recognition *(speech, images)*
  - Financial algorithms *(credit scoring, algo trading)*
  - Energy forecasting *(load, price)*
  - Biology *(tumor detection, drug discovery)*
  - Engineering *(fleet analytics, predictive maintenance)*

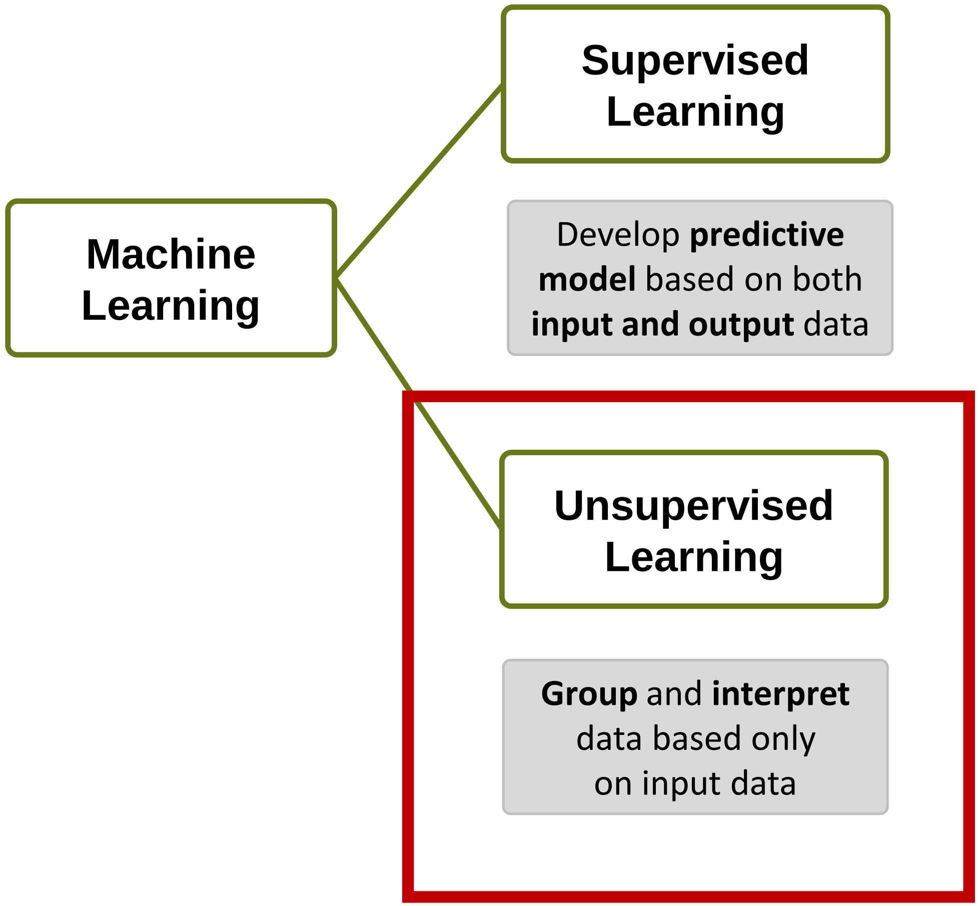




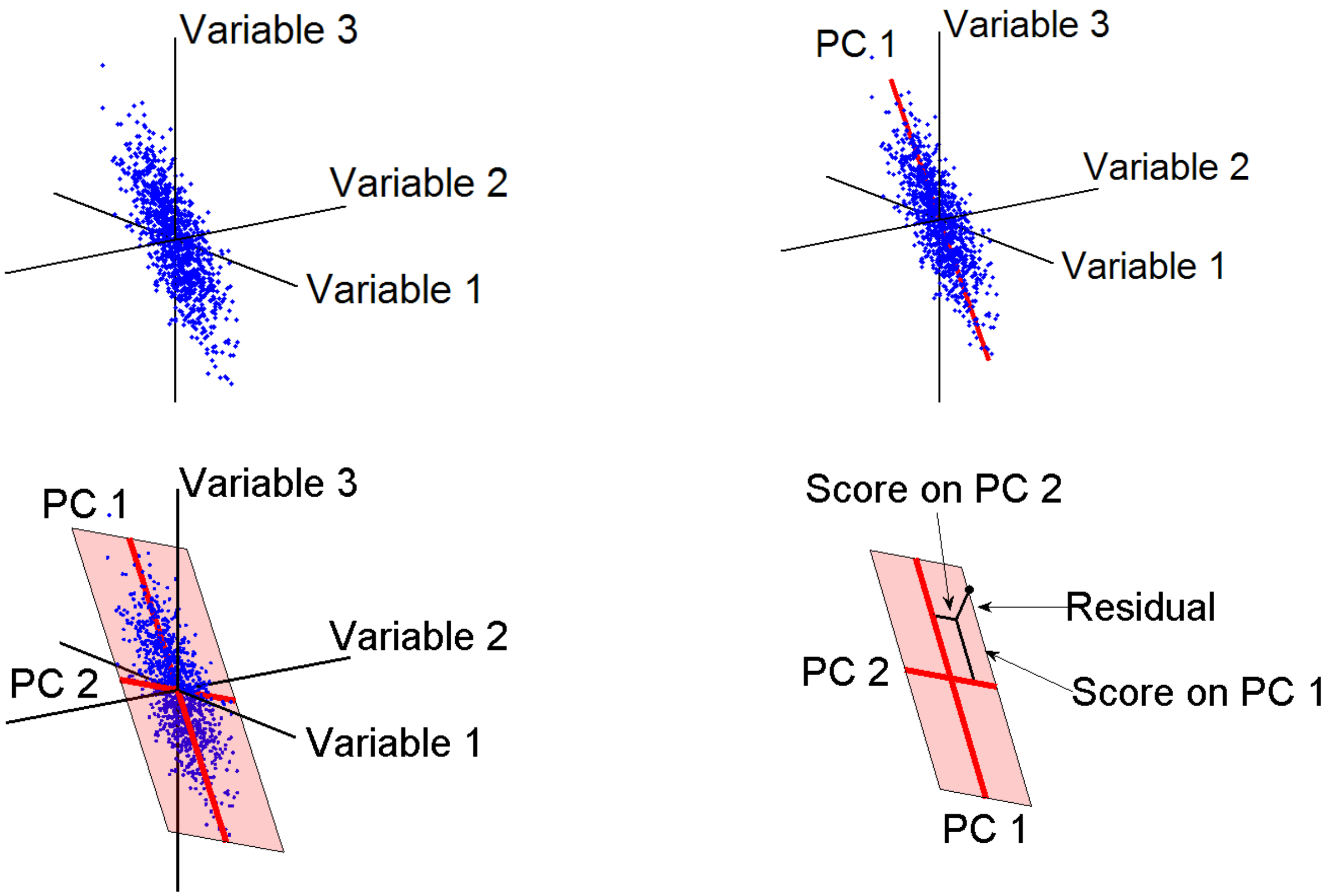


Overview – Machine Learning

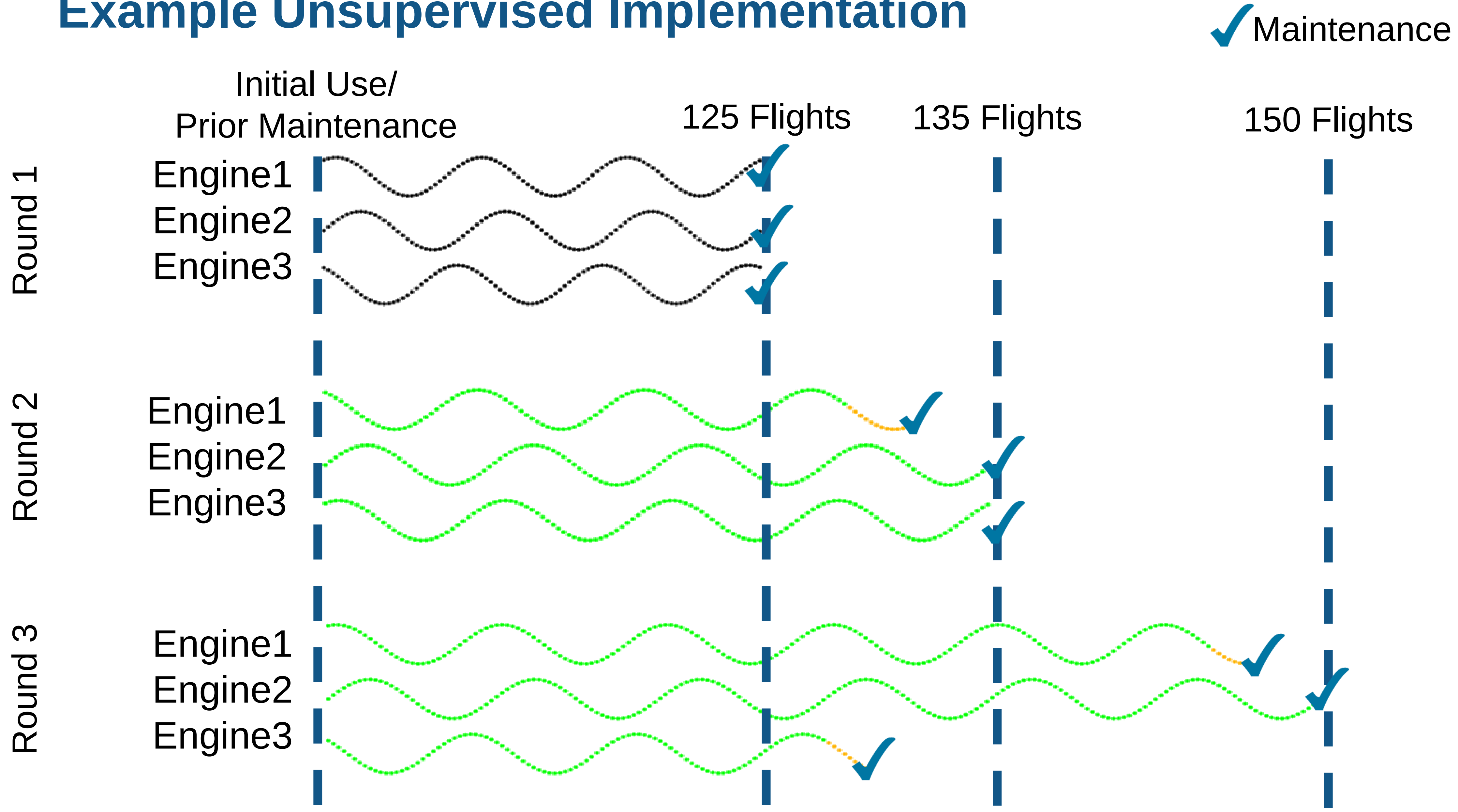
Type of Learning



Principal Components Analysis – what is it doing?



Example Unsupervised Implementation

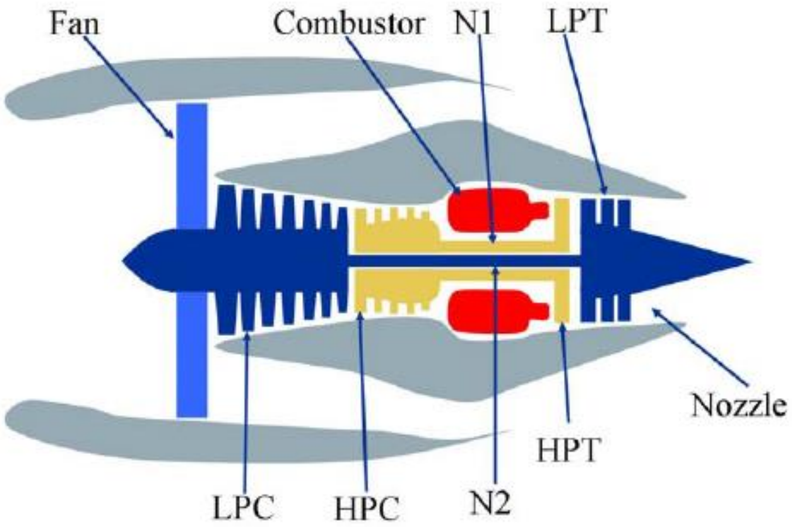


Predictive Maintenance of Turbofan Engine

Sensor data from 100 engines of the same model

Scenario 2: Have failure data

- Performing scheduled maintenance
- Failures still occurring (maybe by design)
- Search records for when failures occurred and gather data preceding the failure events
- Can we predict how long until failures will occur?



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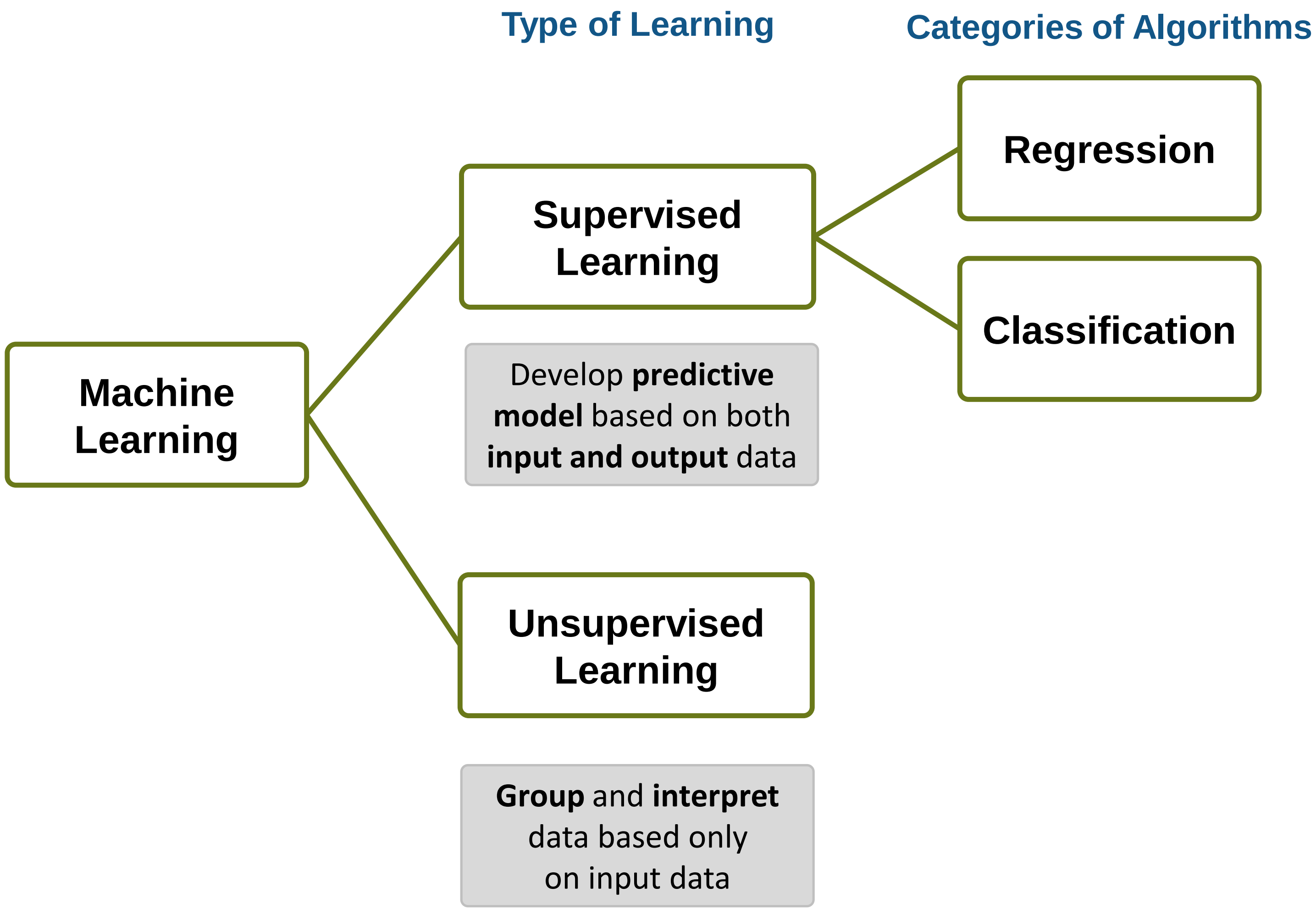
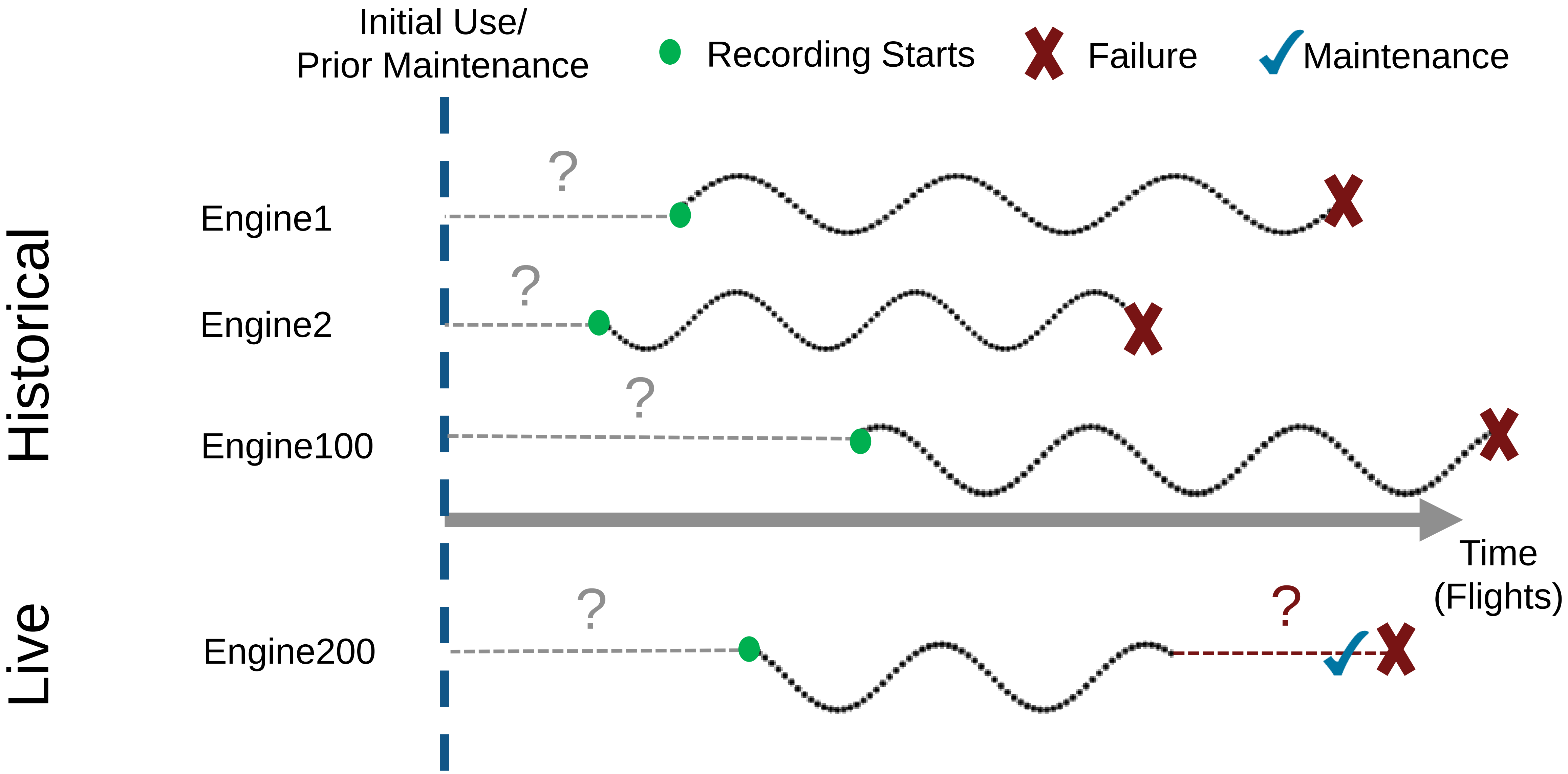
Overview – Machine Learning

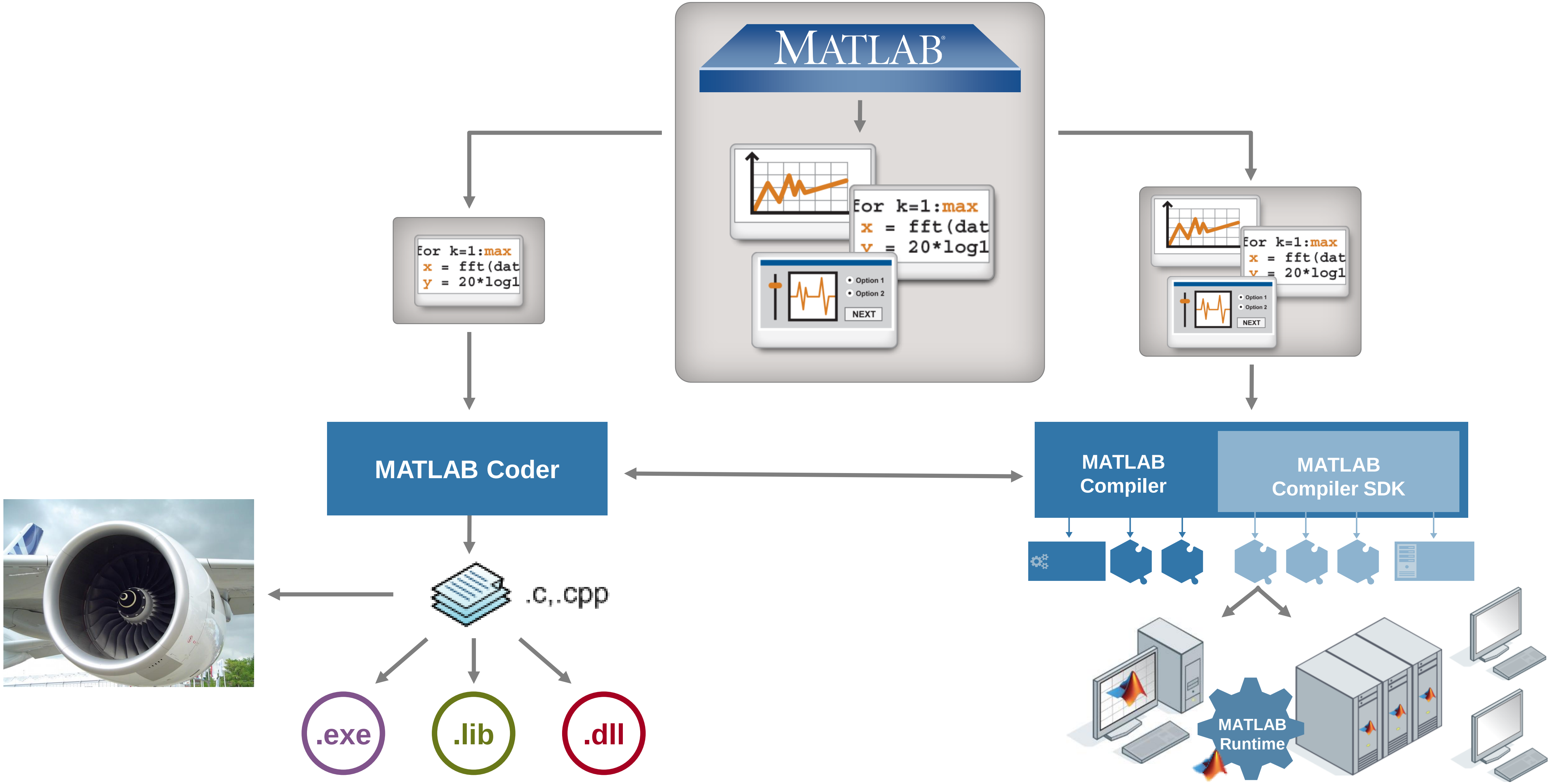


How Data was Recorded



Integrate analytics with your enterprise systems

MATLAB Compiler and MATLAB Coder



MathWorks Services

- Consulting
  - Integration
  - Data analysis/visualization
  - Unify workflows, models, data

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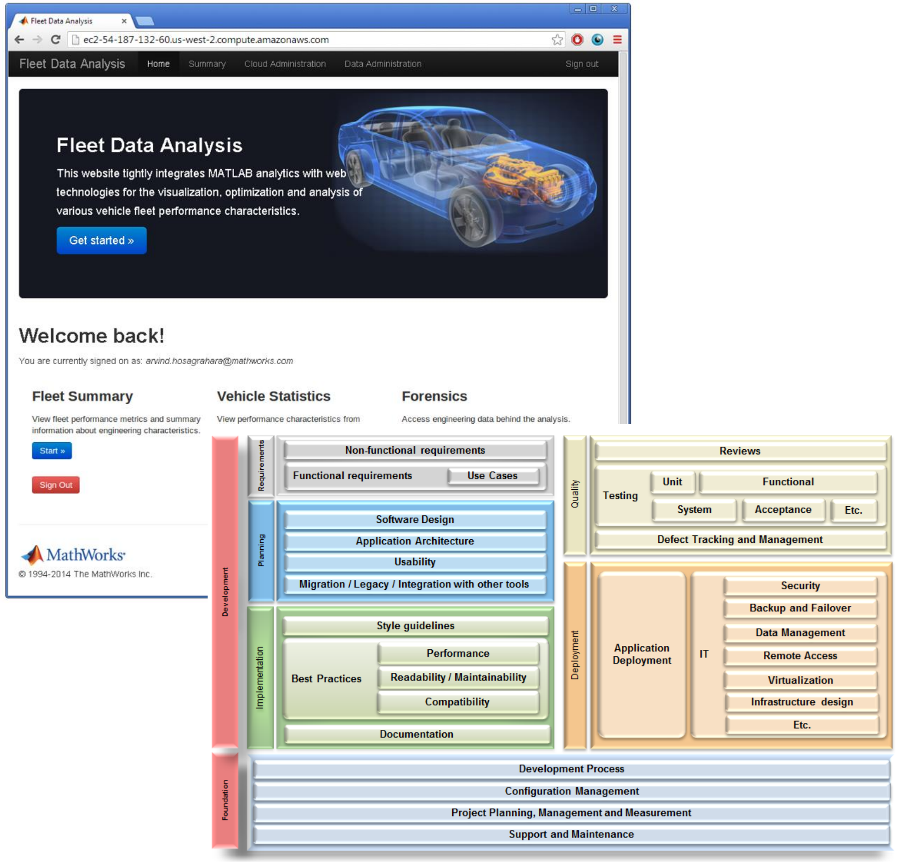

- Training
  - Classroom, online, on-site
  - Data Processing, Visualization, Deployment, Parallel Computing

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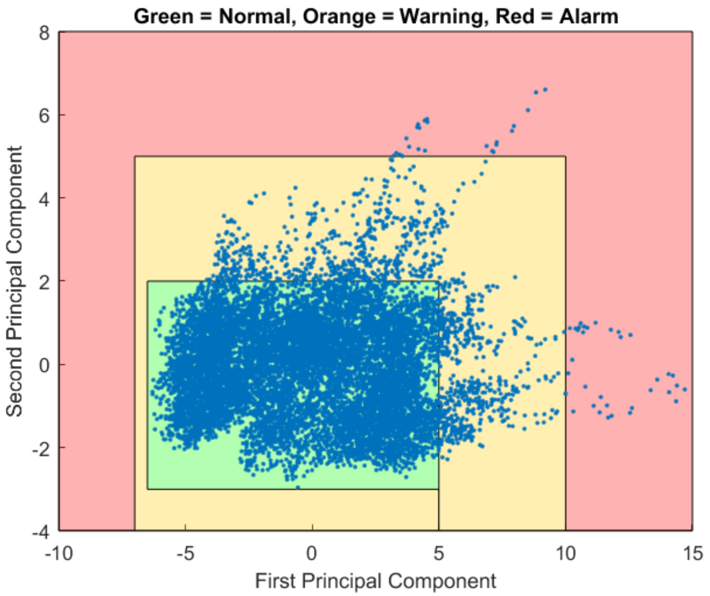
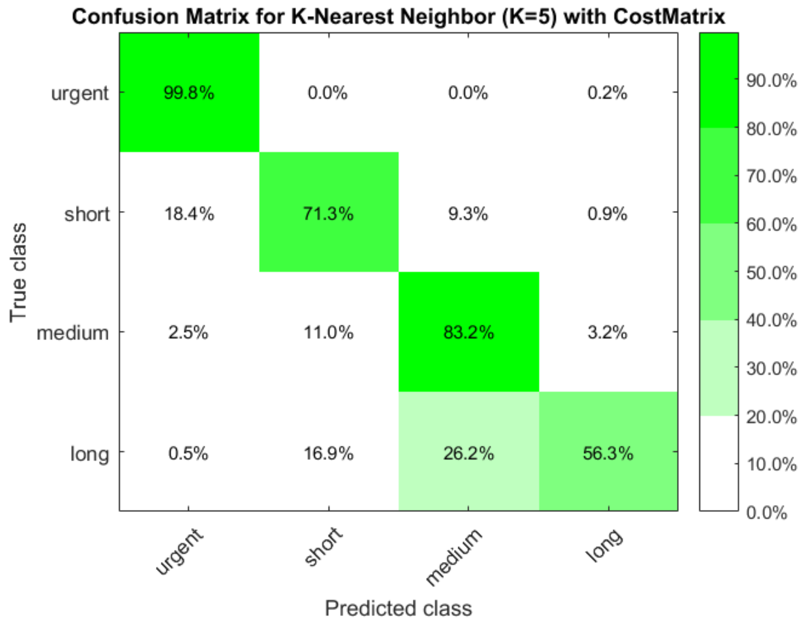
Key Takeaways

- Frequent maintenance and unexpected failures are a large cost in many industries
- MATLAB enables engineers and data scientists to quickly create, test and implement predictive maintenance programs
- Predictive maintenance
  - Saves money for equipment operators
  - Increases reliability and safety of equipment
  - Creates opportunities for new services that equipment manufacturers can provide





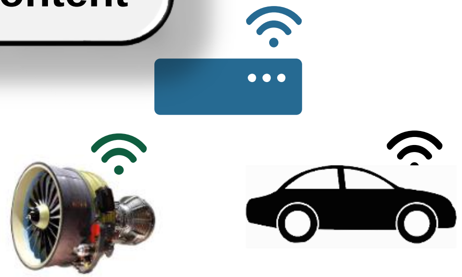
Why MATLAB for Engineering Analytics

1. Analytics that increasingly require **both business and engineering data**

Business Systems

DATA
- Engineering, Scientific, and Field
- Business and Transactional

2. Developing **embedded systems** which have increasing analytic content



Smart Connected Systems

3. Deploying applications that run on **both traditional IT and embedded platforms**

4. Enable **Domain Experts to do Data Science**

Data Analytics

Learn More

www.mathworks.com/discovery/predictive-maintenance.html

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Forecast potential equipment failures

Predictive maintenance (also known as PHM or equipment "health monitoring") refers to the intelligent monitoring of equipment to avoid future equipment failures. In contrast to conventional preventive maintenance, the maintenance schedule is not determined by a prescribed timeline; instead, it is determined by analytic algorithms using data collected from equipment sensors.

Predictive maintenance offers the following benefits for customers and equipment manufacturers:

- Reduce equipment downtime by identifying issues before failure, thereby enabling convenient scheduling of equipment service and extending equipment lifetime.
- Automatic determination of the root cause of the failure, enabling appropriate service to be performed without utilizing resources to determine a diagnosis.
- Avoid the costs of unnecessary maintenance.

Algorithms are critical to predictive maintenance success. Sensor data preprocessing is performed using advanced statistical and signal processing techniques. Machine learning techniques are then used to estimate equipment health.

Once tested, predictive maintenance algorithms may be operationalized in an IT environment such as a server or cloud. Alternatively, algorithms may be implemented in an embedded system directly on the equipment, allowing for faster response times and significantly reducing the amount of data sent over the network.

Lockheed Martin Builds Discrete-Event Models to Predict F-35 Fleet Performance (User Story)

Download White Paper

Fleet Test Data Analytics for Engine and Vehicle Design

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