Predictive Maintenance
Prognostics and Health Monitoring

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Why perform predictive maintenance?

- Example: faulty braking system leads to windmill disaster
  - [https://youtu.be/-YJuFvjtM0s?t=39s](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
- Minimize maintenance costs
- Optimize supply chain

- Reliability
- Cost of Ownership
- Reputation
Aircraft Maintenance

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)
What Does Success Look Like?

Safran Engine Health Monitoring Solution

- Monitor Systems
  - Detect failure indicators
  - Predict time to maintenance
  - Identify components

- Improve Aircraft Availability
  - On time departures and arrivals
  - Plan and optimize maintenance
  - Reduce engine out service time

- Reduce Maintenance Costs
  - Troubleshooting assistance
  - Limit secondary damage

Introduction to SAMANTA

- What is SAMANTA?
  - SAMANTA (Sneca MAtrum Anewing TOOL) is a monitoring environment for Design, Development, and Maintenance items

- Why develop this platform?
  - To enable engineers to quickly and easily lay the knowledge foundations in mathematics or computer science
  - To facilitate exchanges between algorithm developers
  - To capitalize on algorithms
  - To create a complete interface between algorithm results and the system

- Why with MATLAB?
  - To quickly and easily create a platform giving tools through written code or through connecting blo

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

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

- **Supervised Learning**: Develop predictive model based on both input and output data
- **Unsupervised Learning**: Group and interpret data based only on input data
Principal Components Analysis – what is it doing?
Example Unsupervised Implementation

Initial Use/ Prior Maintenance

Engine1
Engine2
Engine3

125 Flights
135 Flights
150 Flights

Maintenance
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?

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

Type of Learning

- Supervised Learning
  - Develop predictive model based on both input and output data
- Unsupervised Learning
  - Group and interpret data based only on input data

Categories of Algorithms

- Regression
- Classification
How Data was Recorded

Initial Use/Prior Maintenance

- **Recording Starts**
- **Failure**
- **Maintenance**

### Historical

- **Engine1**
- **Engine2**
- **Engine100**

### Live

- **Engine200**

- Time (Flights)
Integrate analytics with your enterprise systems

MATLAB Compiler and MATLAB Coder

MATLAB Coder

MATLAB Compiler

MATLAB Compiler SDK

MATLAB Runtime

for k=1:max
  x = fft(data)
  y = 20*log10

for k=1:max
  x = fft(data)
  y = 20*log10
MathWorks Services

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  www.mathworks.com/services/training/
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**
   - DATA
     - Engineering, Scientific, and Field
     - Business and Transactional

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

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

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

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**Smart Connected Systems**

**Business Systems**

**Data Analytics**
Learn More

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