ANA's Predictive Maintenance Challenge

Replace Aircraft Parts Before They Break

Sadanari SHIGETOMI, Naoya KAIDO

Component Operation
Management & Maintenance,
Engineering & Maintenance, ANA

ANA Inspiration of JAPAN

Agenda

1. Our Company
2. Predictive Maintenance of Commercial Aircraft
3. Case Study – Boeing 787 Air Conditioning System
4. Conclusion

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ALL NIPPON AIRWAYS CO., LTD. (ANA)

Foundation	December 27, 1952
Number of employees	13,689 employees (42,196 employees, ANA Group)
Principal Purpose	• Scheduled & Non-scheduled air transportation business • Business of buying, selling, leasing and maintenance of aircraft and aircraft parts • Aircraft transportation ground support business including passenger boarding procedures and loading of hand baggage
Number of Aircraft	• 227 Passenger aircraft Airbus A320, A321, A380, Boeing 737, 767, 777, 787 DHC-8-400 • 11 Cargo aircraft Boeing 767, 777

(as of March 31, 2022)

ANA Inspiration of JAPAN

A STAR ALLIANCE MEMBER

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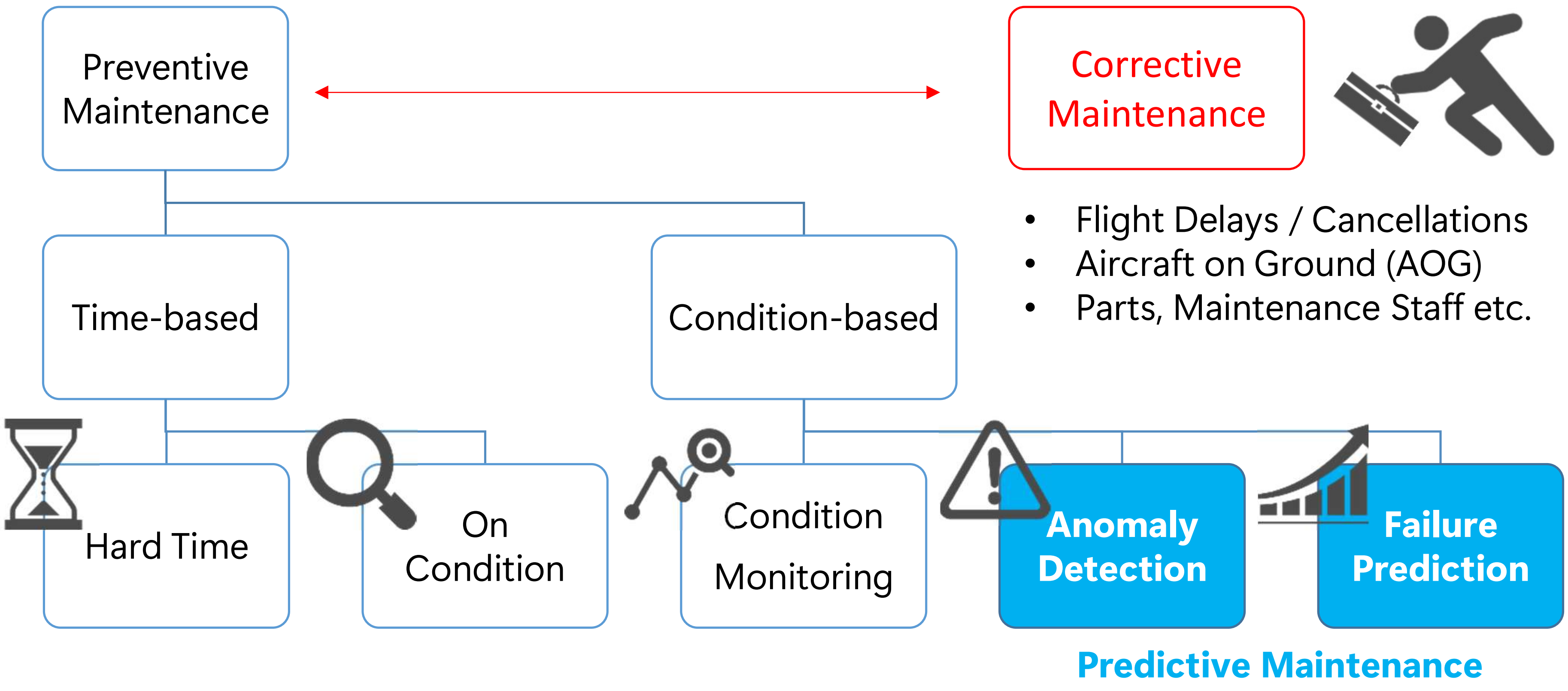
Predictive Maintenance for Commercial Aircraft



✓ Corrective maintenance is always unexpected and costs additional resources.

✓ Predictive maintenance allows work to be performed at the optimal time, before failures.

✓ Data analytics and solution services are also provided from manufacturers and MRO* companies.

*: Maintenance, Repair and Overhaul

What we do with MATLAB®

Operational Data | **Domain Knowledge** × **Data Analysis / Data Science** = **INSIGHTS**

- Time series sensor data (QAR/CPL)

  QAR: Quick Access Recorder, CPL : Continuous Parameter Logging
- Maintenance records etc.

- Visualization
- Hypothesis testing

- Trouble-shooting
- Signs of failure

✓ Various sensor data (QAR/CPL) can be acquired thanks to integration of avionics.

✓ Finding insights requires vast and various data and analysis.

✓ MATLAB can not only visualize and analyze data, but also deploy models easily (p.17).

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Introduction of Air Conditioning System

Airplanes fly high altitude

Function of Air Conditioning System needs

- ✓ Maintain cabin pressure near ground level
- ✓ Maintain comfortability of cabin

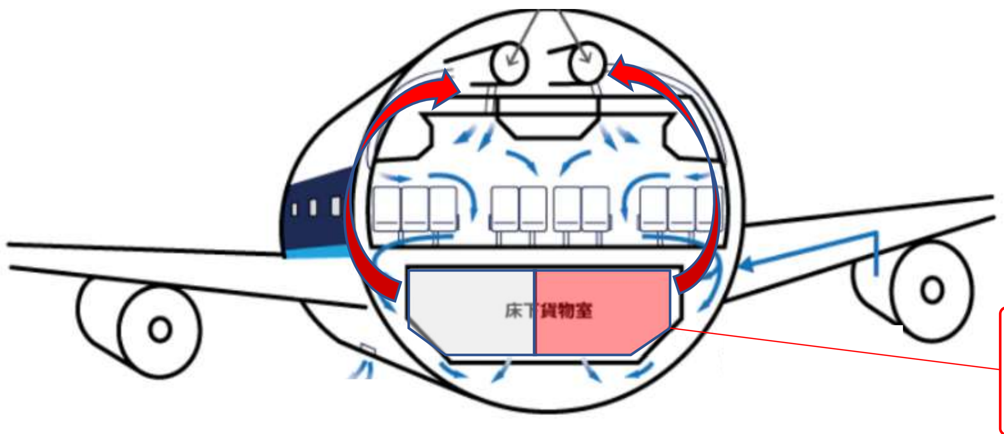
Space of airplane is limited

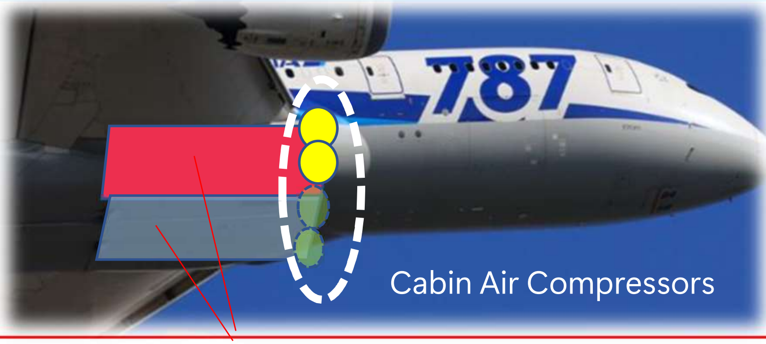
Structure of Air Conditioning System needs

- ✓ Simple
- ✓ Compact
- ✓ Lightweight

Method of Air Cycle Refrigeration satisfy conditions

Location of Air Conditioning System

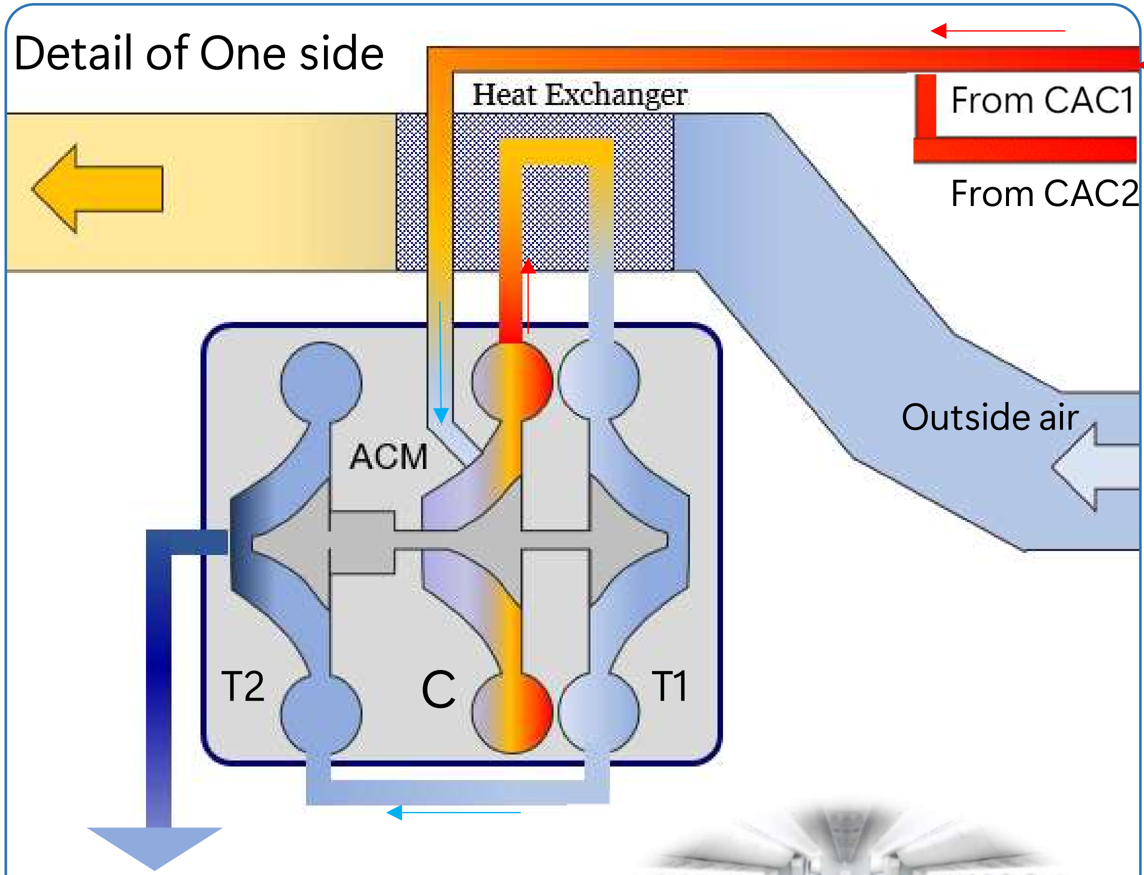




- Set two identical systems for safety reasons
- Located under cabin area (red and blue)

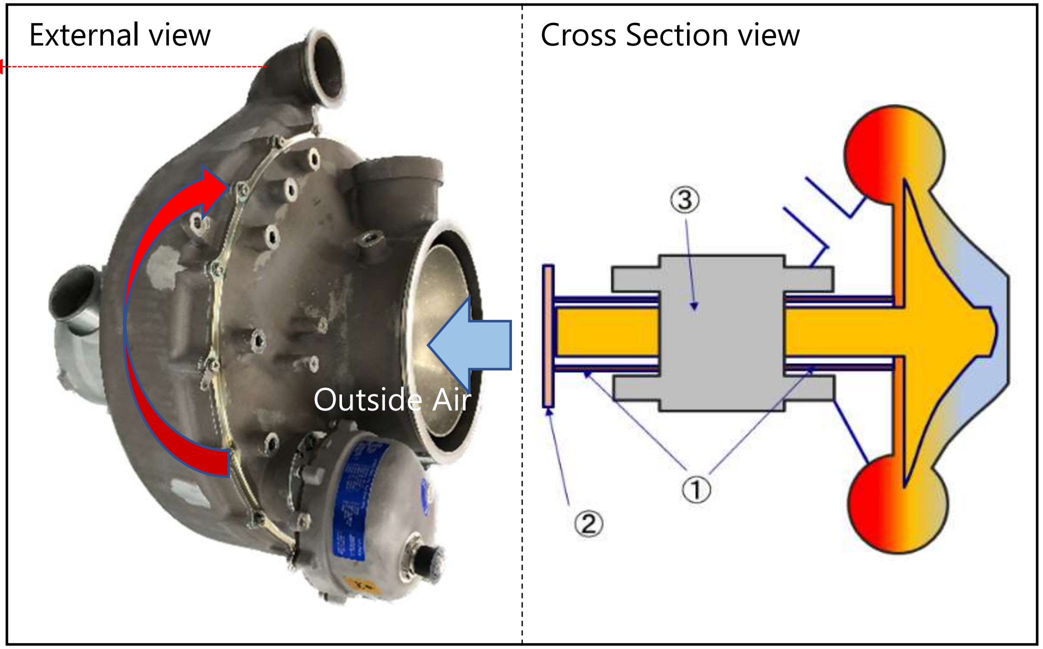
Overview of Air Conditioning System & Cabin Air Compressor

Source Air : **High temperature & High pressure air**



Generate steady air

- ✓ Low temperature
- ✓ Low pressure



Name	Cabin Air Compressor(CAC)
Type	1^{st} stage centrifugal compressor
Role	Compression of outside air
Main parts	①Journal Bearing, ②Thrust Bearing, ③Stator, ④Shaft, ⑤Impeller
Specification	Type of Bearings are Air Bearing

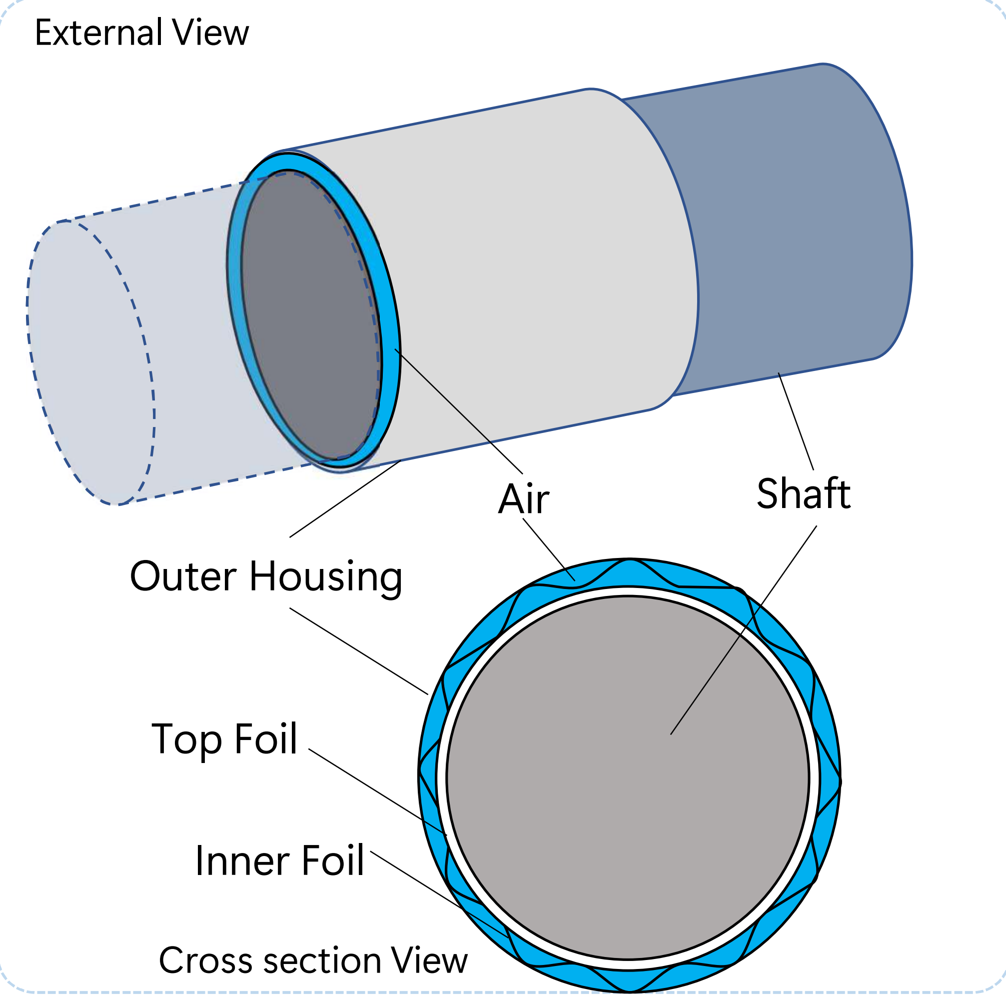
Process of Analysis

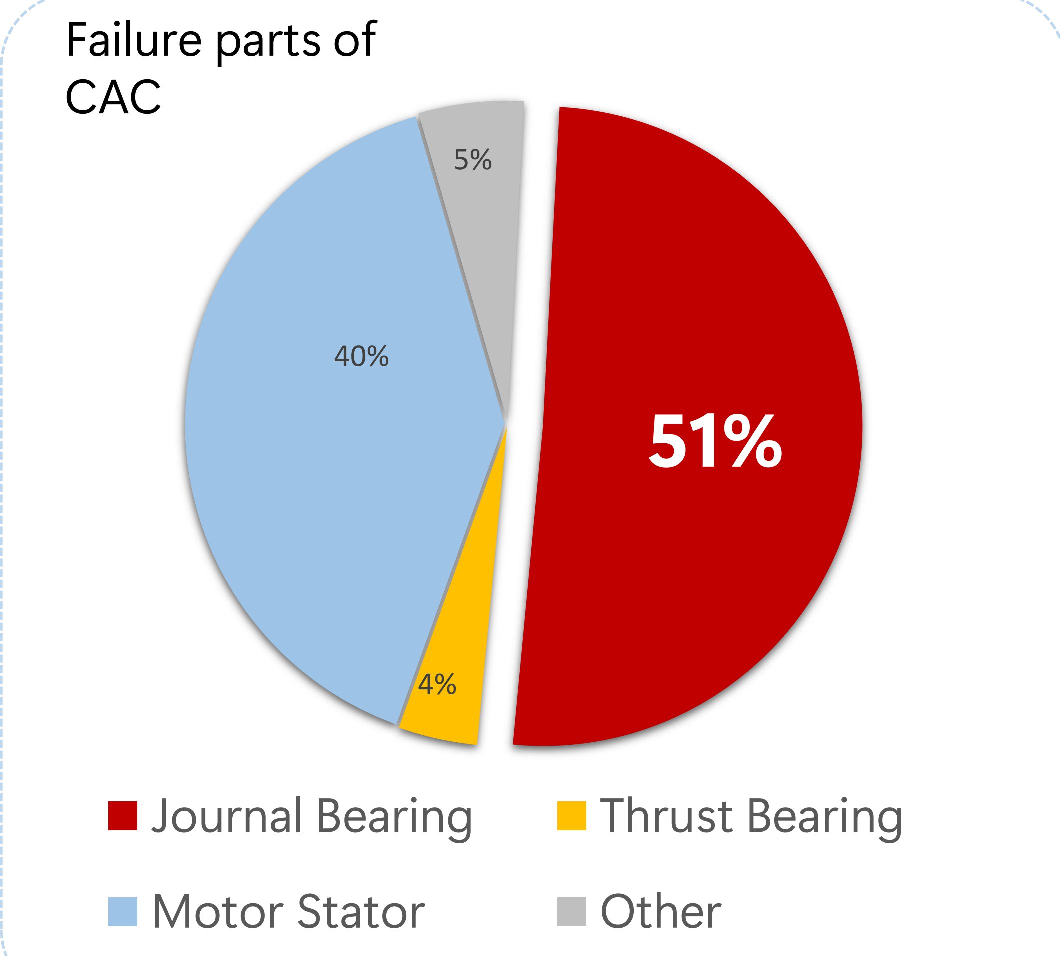
Decision of Target Failure → Hypothesis Planning → Hypothesis Verification

Process of Analysis 1

Decision of Target Failure

Target Failure : Journal Bearing Failure





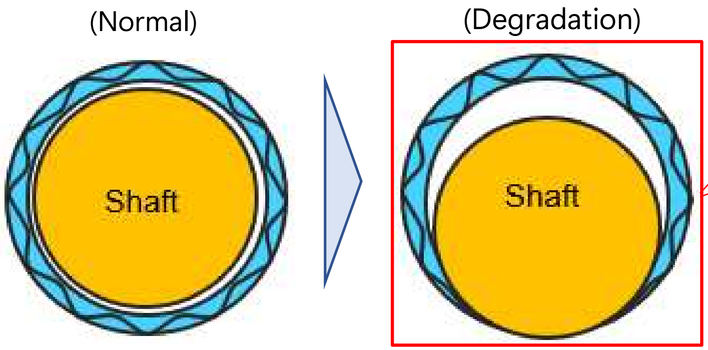
Process of Analysis 2

Hypothesis Planning

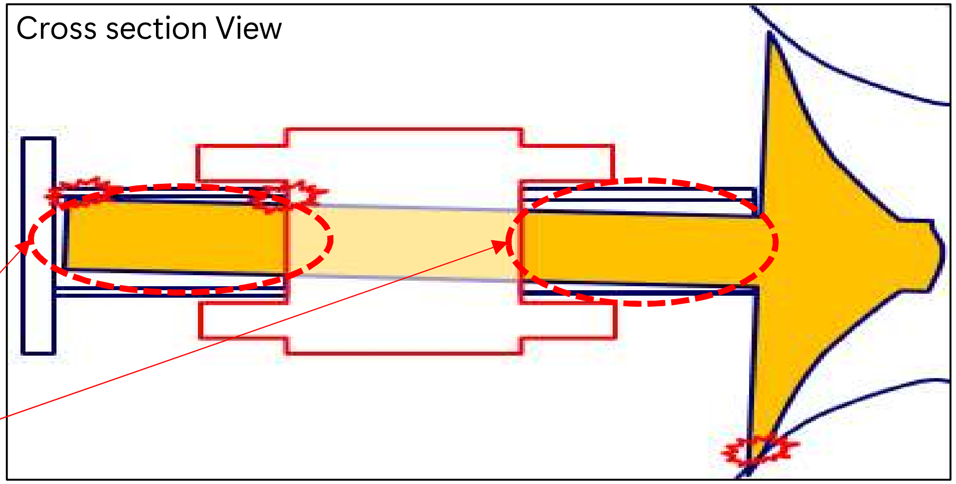
Use deep domain knowledge (2 elements)

Knowledge from Component

- ✓ Confirm condition of Journal Bearing
- ✓ Confirm other degradation



Inner of Journal bearing is deformed when degrade



Degradation is related to other failure

- Rubbing (Contact Impeller & Housing)
- Burn out Stator (Contact Shaft & Stator)

Knowledge from Document or Flight Data

- ✓ Clarify operation & Behavior of CAC or Components around CAC

Process of Analysis 3

Hypothesis Verification

Verify the hypothesis based on flight data

Based on Hypothesis & Flight data

Method

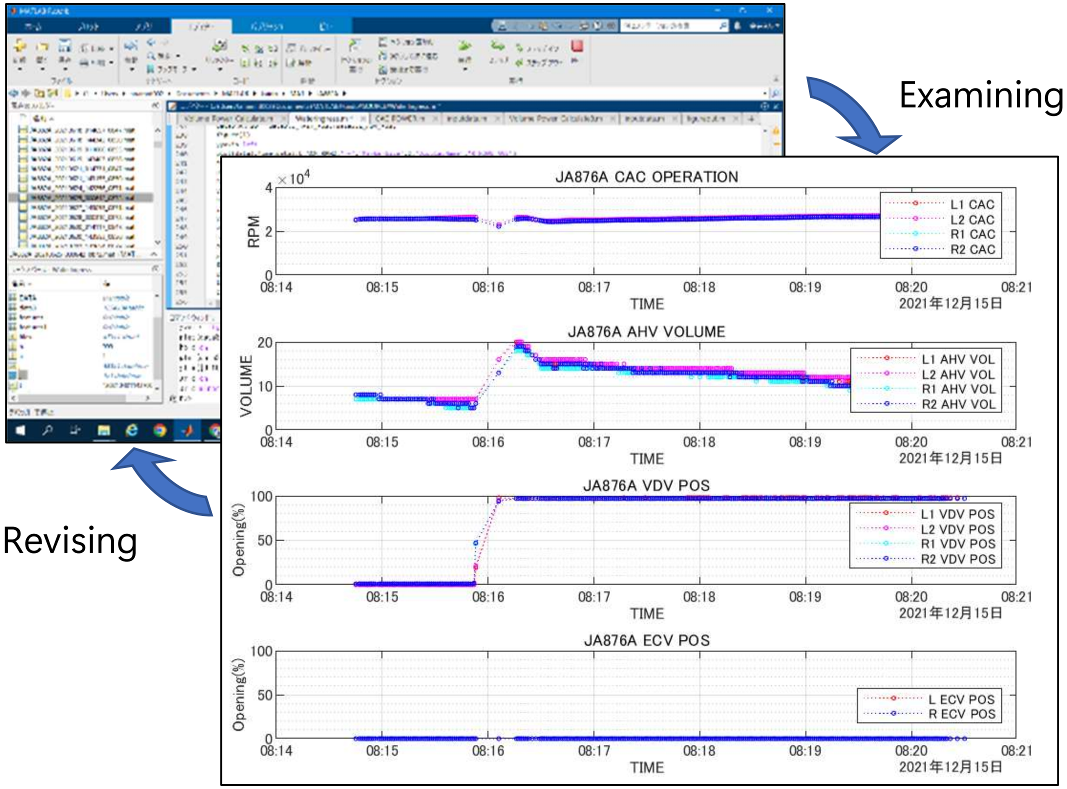
Using about 300 flight data.
(About 1 year of an aircraft)

Download Flight Data from Server by CSV file

Conversion to MAT file

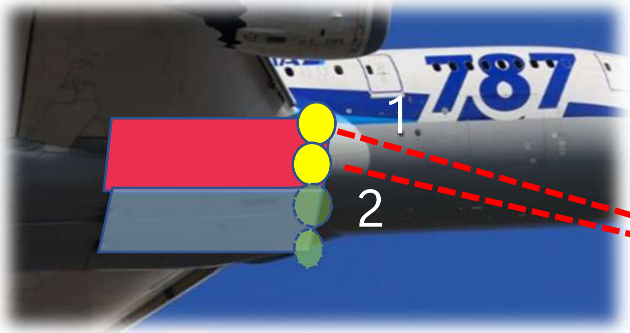
Examining

Revising



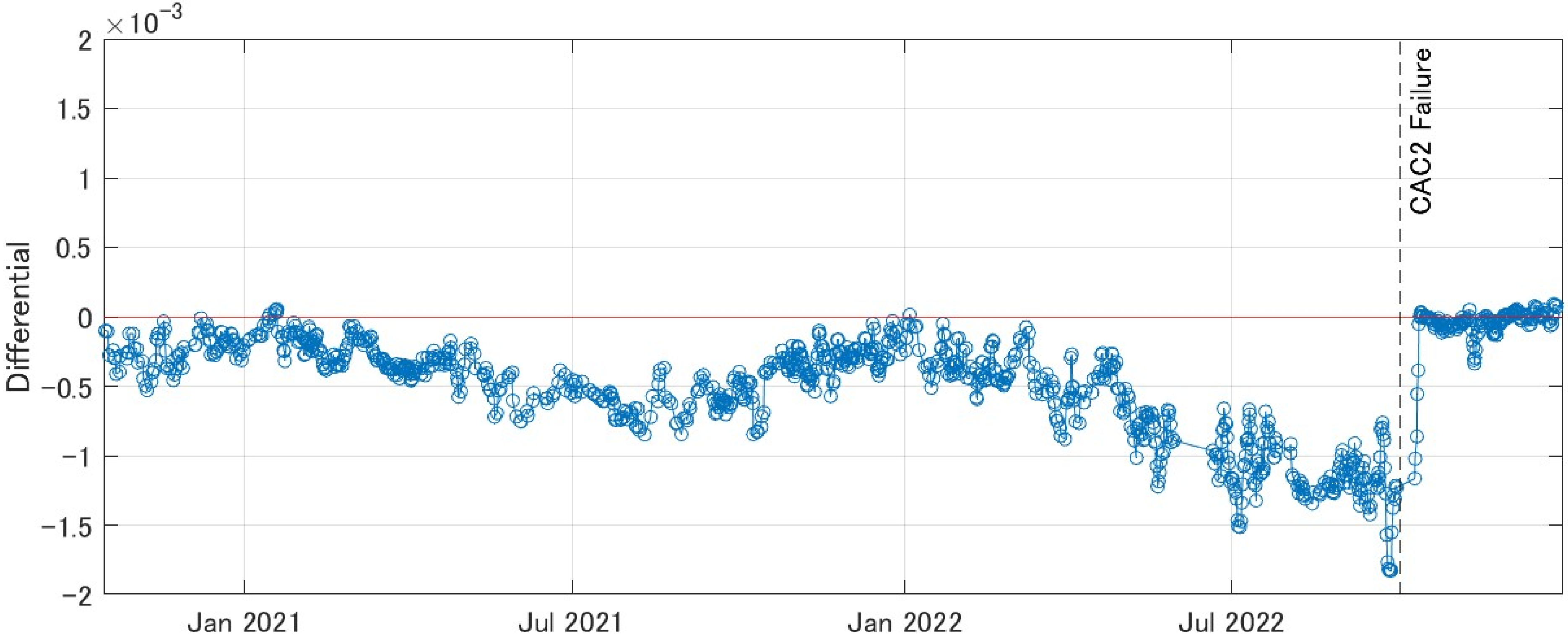
Find feature of degradation on repeating trial and error

Result of Detection



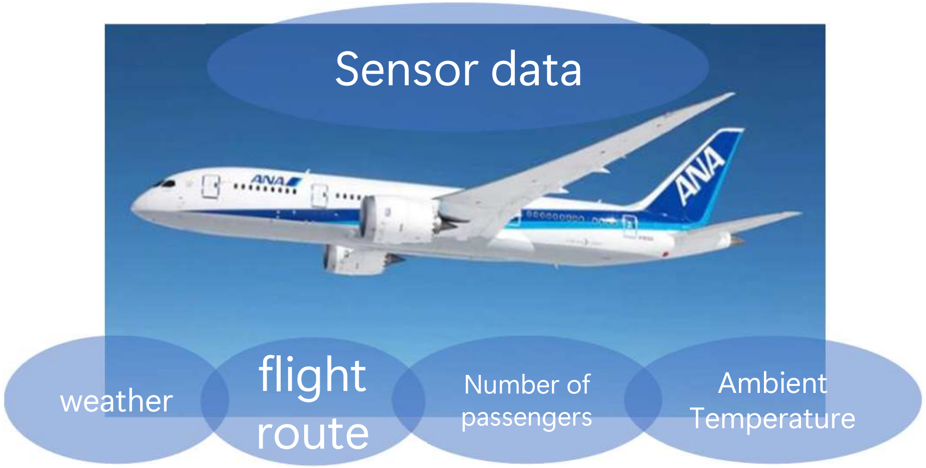
A. Calculate average of a parameter on a part of flight

B. Compare other CAC operating in parallel
-Calculate difference of CAC1 and CAC2

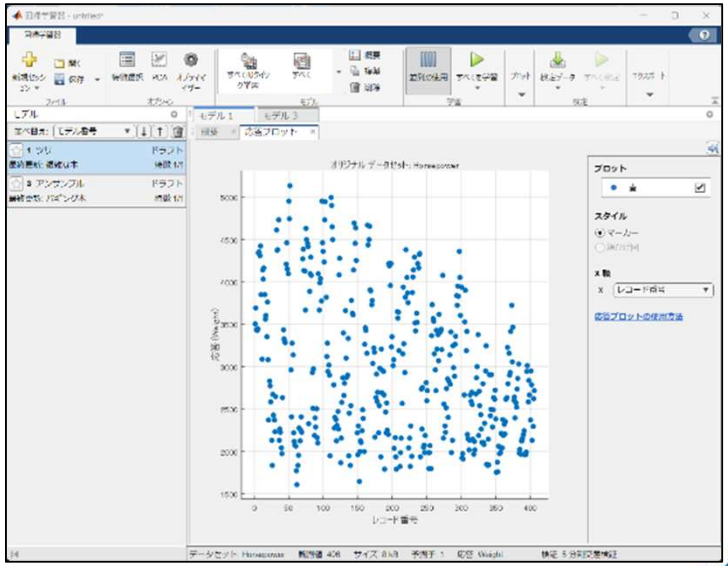


Found balance of CAC 1&2 was collapsed before failure

Application of Machine Learning



historical data for 10,000+ flights

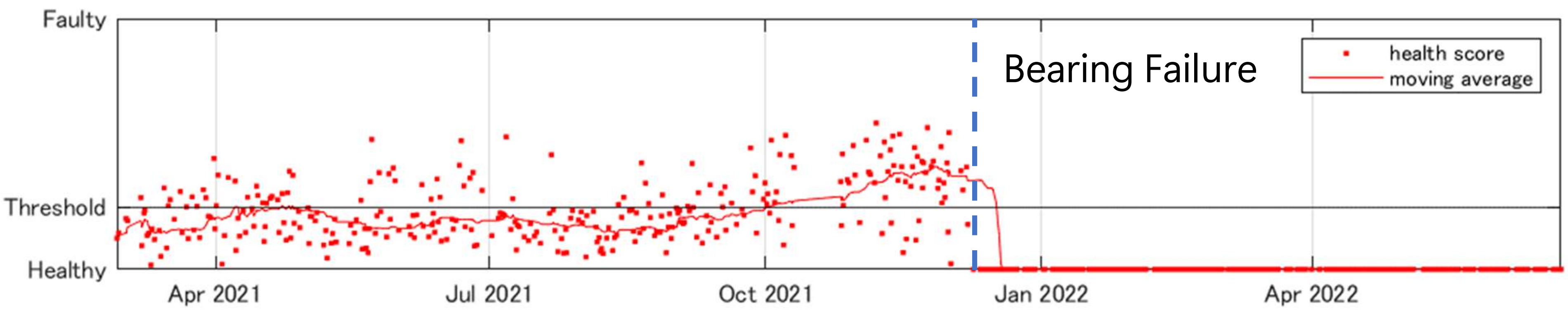


Developed a classification model
<u>Statistics and Machine Learning Toolbox™</u>
<u>- Classification Learner (Narrow Neural Network)</u>

✓ Comparing two systems running in parallel can make it challenging to set a threshold.

✓ A machine learning model was developed using features extracted from sensor and external environment data. True labels were extracted from maintenance records.

Results / Prediction Accuracy



Machine learning model-based degradation index - validation

Precision

= True Positives
/ Retrieved Cases

77%

Recall

= True Positives
/ All Failure Cases

23%

✓ The model-based degradation index tends to increase as the failure approaches.

✓ Placed a higher priority on precision to avoid false-positive alarms.

Deploy and Operation

Data Correction

Sensor data during flight

Other external environments

Data Processing

- ✓ Pre-processing
- ✓ Estimation by ML model
- ✓ Output results

Monitoring / Visualization

- ✓ Degradation dashboard
- ✓ Maintenance Planning

Automated data pipeline by MATLAB Compiler™

Several CAC bearing degradations were found before failure

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Conclusion

- ✓ **Predictive maintenance** reduces aircraft downtime and improves the overall efficiency.
- ✓ Complex system data analysis (e.g. flight data) requires **domain knowledge**.
- ✓ Operators are trying to find **insights** from their domain knowledge and operational data.
- ✓ Case study shows that the **machine learning** can be also applied to anomaly detection based on the insights.

Future Goals

- ✓ Improve **the precision & recall**, as well as **the interpretability** of machine learning models.
- ✓ Accelerate **"Data-driven maintenance"** in order to improve our productivity.

THANK YOU