Optimizing Compressor Wash Intervals for Aircraft Engines

INTRODUCTION + OBJECTIVE

Create an algorithm that can label when a Rolls-Royce AE3007 engine has reached its compressor wash interval. Show this on an interactive application where clients/operators can see when the aircraft engine requires a compressor wash.

What is a compressor wash interval?

- Aircraft engines occasionally operate in a corrosive environment (salinity, dust, industrial particulates, etc.)
  - Material properties can degrade
    - Cause engine failure
  - Each engine has a "health bar" before it needs to go in for maintenance
    - Remove the internal and external contamination by washing/cleaning the engine

What did we use?

- R in RStudio for Data Analysis, Cleaning, and Wrangling
- R Shiny Package to build an interactive app
  - Show engine flight path and time spent in corrosive environment

What we started with

- Public flight data from Department of Transportation Statistics
- Rolls-Royce engine data
- Map of the corrosive environments in the US

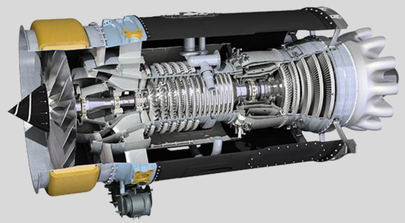


Figure 1: Rolls-Royce Engine AE3007, taken from https://www.rolls-royce.com/products-and-services/civil-aerospace/business-aviation/ae-3007.aspx#section-technology

STAGE 1: DATA WRANGLING

Merge the Rolls-Royce dataset and the public commercial flight dataset so we can map each engine to a plane. This adds on locational data to each engine, allowing us to track where each engine travels and see whether it operates in a corrosive region.

Two step process:

1. Clean the data so it is in a readable useful format
   - Refer to Figure 2
2. Match datapoints from each dataset based on three criteria
   - Refer to Figure 3

In the end, we have 500,000 points of Rolls-Royce engines mapped to public commercial flights over 5 years (refer to Figure 4)

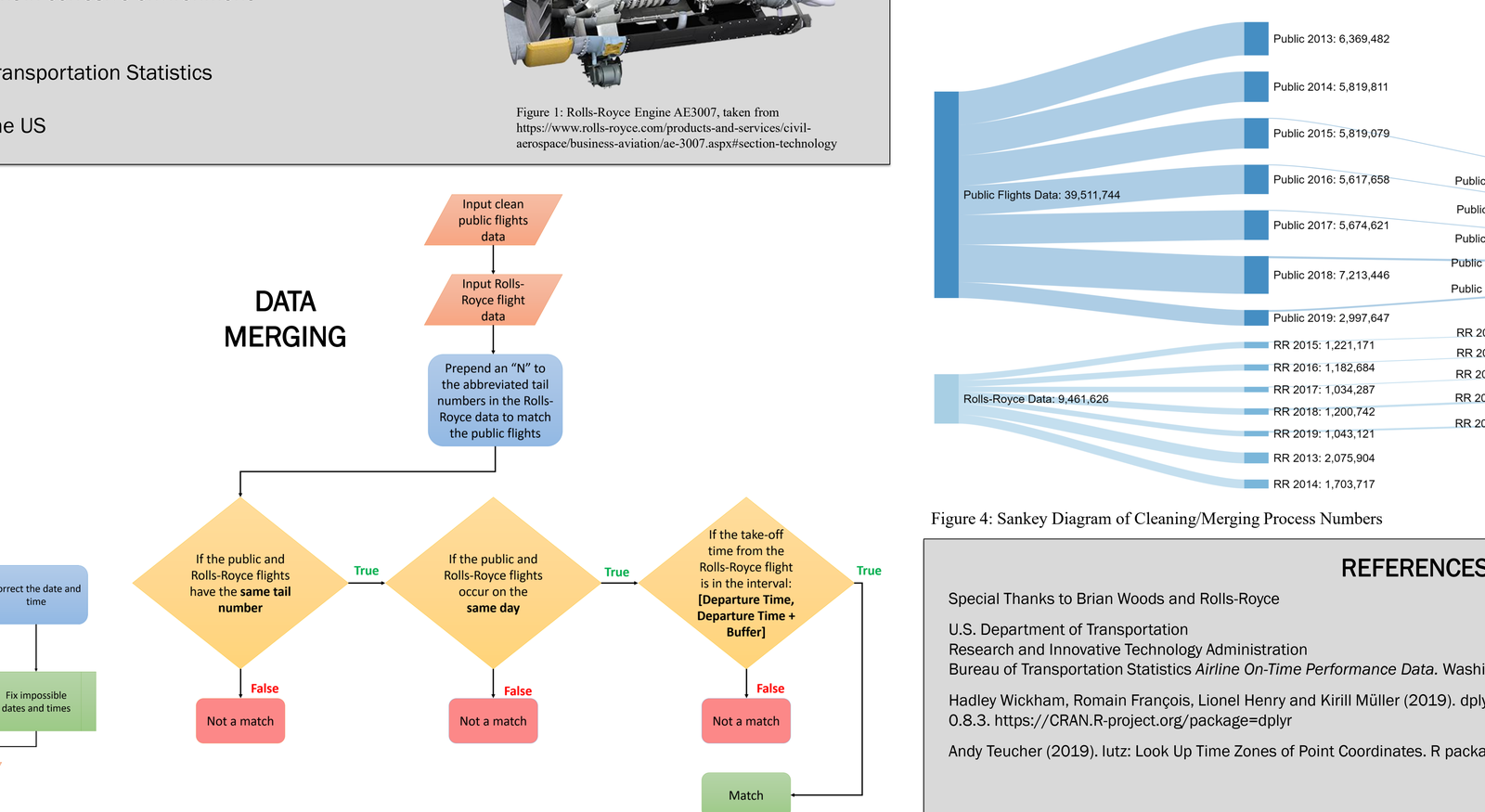


Figure 2: Flowchart of Data Cleaning Process

Figure 3: Flowchart of Data Merging Process

Figure 4: Sankey Diagram of Cleaning/Merging Process Numbers

REFERENCES

Special Thanks to Brian Woods and Rolls-Royce

U.S. Department of Transportation
Research and Innovative Technology Administration
Bureau of Transportation Statistics *Airline On-Time Performance Data.* Washington, DC: 2020

Hadley Wickham, Romain François, Lionel Henry and Kirill Müller (2019). dplyr: A Grammar of Data Manipulation. R package version 0.8.3. https://CRAN.R-project.org/package=dplyr

Andy Teucher (2019). lutz: Look Up Time Zones of Point Coordinates. R package version 0.3.1. https://CRAN.R-project.org/package=lutz

Investigating the AE 3007A Engine (Mapping/Methodology)

PROJECT BACKGROUND

Goal: Map interactively in Shiny in order to see if flight's history and travel locations warrant compressor wash

Compare Rolls Royce Flight information against public flight data provided by the Federal Aviation Administration.

WHY SHINY?

Powerful web app development tool
For this project we are using Shiny to:

- Map flight paths,
- Create a visualization of corrosive regions
- Display which engines most warrant compressor cleaning

PROBLEMS AND CHALLENGES

- Credit/debit system to gauge how much corrosion a flight would be susceptible too was not feasible
- Encountered many confounding variables (i.e. where a plane stays overnight)
- Overlaying maps led to some guesswork in determining what latitude and longitude to use based on the scale of initial map

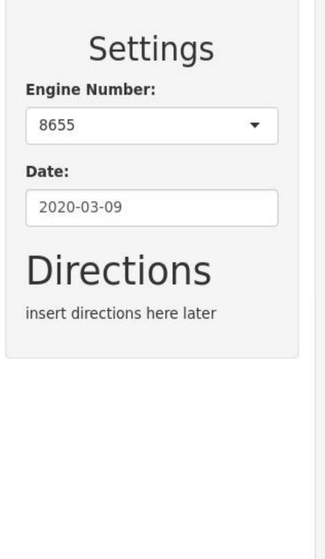
ACKNOWLEDGEMENTS + REFERENCES

- We would like to recognize Brian Woods and the Rolls Royce
- In addition we want to thank The Data Mine, Purdue University, Dr. Mark D. Ward and Margaret Betz

- Shiny from RStudio. (n.d.). SuperZip example. Retrieved February 29, 2020, from https://shiny.rstudio.com/gallery/superzip-example.html

APP METHODOLOGY

- Transposed Rolls Royce map onto a map of respective U.S. counties (see Figure 1)
- Recorded where 3000 counties lay based on zone (mild, moderate, severe) using Excel and R (see Figure 2)
- Extract the ZIP code database from Zip-Codes.com (~40,000 ZIP codes with both city and county information
- Utilized public ZIP code database from the US Census Bureau and latitude/longitude information to ensure accuracy (worked with 43,000 codes with city and latitude/longitude information)
- Using R, the data were cleaned and merged, using county information and latitude/longitude to map the counties based on corrosion zones across the continental United States
- Formatted mapping into an app through Shiny (see Figure 3)



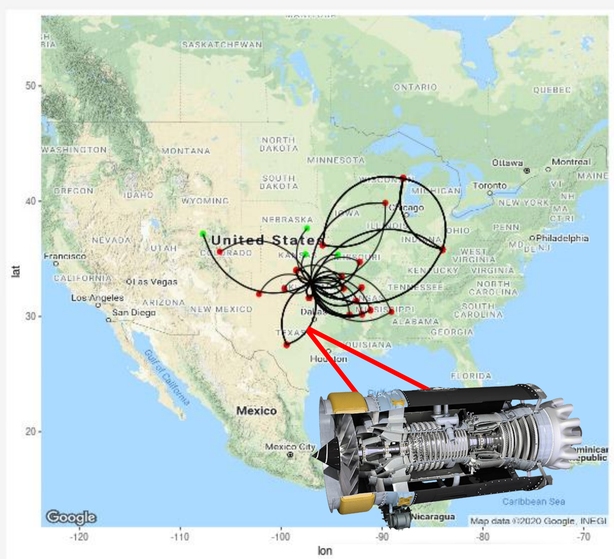


Figure 3: Shiny app interface of flight mapping

Figure 2: Shiny app interface of flight mapping

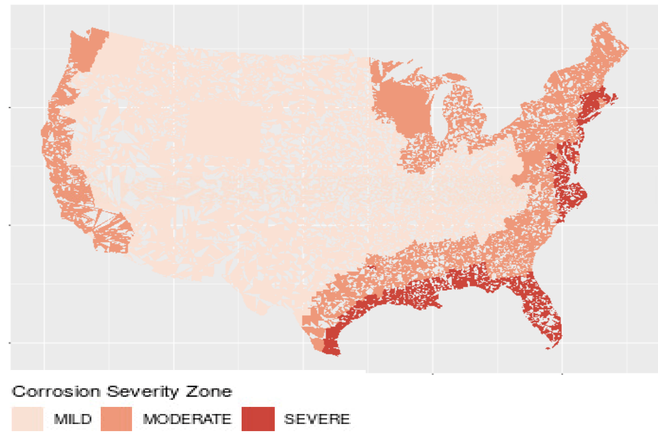


Figure 1: Map of corrosive regions provided by Rolls-Royce

Compressor Wash Interactive Analysis Tool

INTRODUCTION TO ANALYSIS TOOL

The main goal of this application was to highlight a specific engine's flight patterns and its impact with corrosive regions. This is done through the following:

1. INPUT FIELDS (FIGURE 1)
2. DATA DISPLAYS (FIGURE 3)
3. AN INTERACTIVE MAP (FIGURE 2)

INPUT FIELDS

The app is configurable using the following inputs:

- **Date Range:** The user may select any range of dates for which there is data available.
- **Engine Numbers:** The list of all matched engines can be searched, and the user may select as many as they like to display
- **Mild Region:** Checking the 'Show Mild Region' check box will display the mild region as a polygon on the map

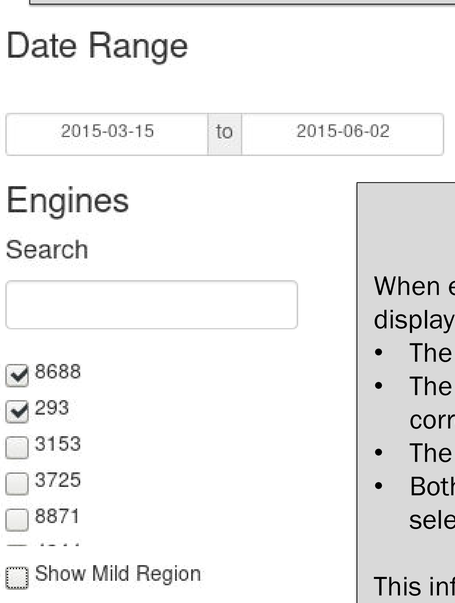


Figure 1: Input Fields

DATA DISPLAY

When engines and dates have been selected, the app will display some simple statistics including:

- The total number of days considered
- The total flights per engine that go through the corrosive region (marked red on the map)
- The total number of hours spent in the corrosive region.
- Both statistics are dependent on the time frame selected

This information can give the engineers a good idea of which engines need to be washed.

INTERACTIVE MAP

The map provides visualization of the selected data including:

- Lines connecting origin to destination for all flights
- Coloring based on whether the flight passed out of the mild region
- The ability to pan, zoom in and out, and view arbitrary landmarks such as cities and state borders
- Clicking on a flight will display a pop-up revealing the date, engine number, tail number, origin and destination airport codes of that flight.

Figure 2: Interactive Map

Number of Corrosive Flights

Engine Number	Total Flights
293	244.00
8688	280.00

Time flown in Corrosive Region (hours)

Engine Number	Total Time
293	363.55
8688	421.75

Figure 3: Data Display