CEE 5614: Analysis of Air Transportation Systems Spring 2022

Assignment 3: Aircraft Performance Calculations

Date Due: February 16, 2022 Instructor: Trani

# Problem 1

Using the fundamental equation of motion explained in class and the fundamental lift equation (see equations below) explain in three sentences, the following questions:

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1. The effect of airport elevation in takeoff speed.
2. The effect of airport elevation in aircraft acceleration during takeoff.
3. The effect of airport elevation on engine thrust.
4. The effect of runway gradient on aircraft acceleration.
5. The effect of aircraft mass in the acceleration during takeoff.
6. The effect of mass and airport elevation on takeoff distance.

## Problem 2

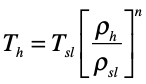
A new low-cost airline is evaluating two aircraft to operate flights from Washington, Reagan Airport (DCA) to two important airport destinations. The following table shows the aircraft proposed by airline executives to operate from DCA. The critical stage lengths the airline would like to fly with the selected aircraft are: a) DCA-DFW and b) DCA-DEN.

Table 1. Aircraft Considered in the Airline Evaluation.

| Aircraft Considered |
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| Boeing 737-8 Max with CFM LEAP-1B28B1 engines. Aircraft maximum design takeoff weight is 182,200 lb. a two-class seating layout. |
| Boeing 737-800 (with winglets) powered by two  *CFM56-7B27-B1 engines rated at 26,000 lbs of thrust at sea level static conditions - SLST)*). Aircraft maximum design takeofff weight is 174,200 lb. The aircraft has 160 seats in a two-class layout. |

The design airport temperature used should be the average of the maximum daily temperatures of the hottest month of the year. Use the Climate Explorer website (<https://crt-climate-explorer.nemac.org/climate_graphs>) to find the mean maximum temperature of the hottest month of the year. More detailed information about the airport can be found at the AIRNAV database available on the web at: <http://www.airnav.com/airports/> or visit the airport site.

In your analysis use the latest version of the Boeing documents for airport design (http://128.173.204.63/courses/cee5614/sites\_ce\_5614.html#Aircraft\_Data).

1. Find the average stage length to be flown between each one of the critical OD airport pairs. In your analysis use the Great Circle Flight Path mapper link provided in our interesting web sites. Add 6% to the distances calculated to account for real Air Traffic route conditions and to account for possible weather deviations from the optimal Great Circle flight path.
2. Find the runway length needed for each one of the aircraft operating the critical route. Determine if DCA has enough runway length to support these flights with a passenger load factor of 85%.
3. Estimate the average fuel per passenger assuming a load factor of 0.85 (85% of the seats used) for both routes. Can the airline achieve good fuel savings using the new Boeing 737-8 Max compared to the standard Boeing 737-800?
4. Using the Payload-Range diagram of each aircraft, and using the longest flight of the two routes, find the Specific Air Range (SAR) parameter for each aircraft. SAR is the number of miles traveled divided by the amount of fuel used (similar to fuel efficiency in cars). Comment on the SAR values calculated.
5. Considering various factors which aircraft is the best for this airline? Explain.

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Figure 1. Boeing 737-800 (above) and Boeing 7378Max (below). Larger diameter engines and chevrons on the back of the engine cowlings distinguish the Boeing 737-8Max. The Scimitar winglets are standard on new Boeing 737-8Max models and also available in later Boeing 737-800 models. Source: A. A. Trani.

# Problem 3

1. An airline is evaluating future operations out of Salt Lake City International Airport (SLC). The airline is considering buying three new generation twin-engine aircraft and is evaluating the Boeing 787-8 (with maximum takeoff weight of 502,500 lbs., Rolls-Royce engines, and mixed class seating configuration) and the Boeing 787-9 (with maximum takeoff weight of 560,000 lbs., Rolls-Royce engines, and mixed class seating configuration). The airline would like to fly from SLC to European cities including Madrid (MAD) Spain and Dublin (Ireland). In this analysis consider the runway length available at SLC (consult airnav webwite). Use the Climate Explorer website (<https://crt-climate-explorer.nemac.org/climate_graphs>) to find the mean maximum temperature of the hottest month of the year at SLC Airport to use in the analysis. In your analysis add 6% to the distances calculated to account for real Air Traffic route conditions and to account for possible weather deviations from the optimal Great Circle flight path

For the aircraft in question investigate the following:

1. What is the design temperature at SLC for runway analysis? How does it compared to ISA conditions?

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Figure 2. Boeing 787-8 (above) and Boeing 787-9 (below). Boeing 787-9 is around 20 feet longer. Note five more windows between the last two fuselage doors. Three more windows between the first two front doors. Source: A.A. Trani.

1. Estimate the takeoff field length required to fly the route SLC-MAD (Madrid) with a 90% passenger load? Can both aircraft fly the route SLC-MAD with 90% load factor? Consider the runway length available at SCL today. Summarize your calculations (OEW, Payload, DTW, Fuel weight, etc.) in a table to justify your answers. **In all your calculations for Problem 3 use the typical engine thrust.**
2. How much additional belly cargo in the form of standard LD-3 containers can each aircraft carry operating from SLC to Madrid? Show me your analysis and calculations. In the calculation, assume the same 90% load factor for passengers.
3. Find the fuel needed to fly each aircraft at passenger 90% load factor. Estimate the cost of fuel per passenger if the IATA fuel cost is $2.55 per gallon (<https://www.iata.org/en/publications/economics/fuel-monitor/>)
4. What version of the Boeing 787 is best suited for this airline? Explain your answer.

# Problem 4

Use the data for the transport aircraft similar to the Boeing 737-800 (http://128.173.204.63/courses/cee5614/cee5614\_pub/Boeing737800Jet\_class.m) to answer the following questions.

1. Calculate total drag produced by the 76,000 kilogram aircraft during a climb profile with an Indicated Airspeed of 250 knots at 3000 meters above mean sea level conditions. Assume atmospheric conditions to be ISA.
2. Repeat the process when the aircraft is climbing at 9,000 meters and an indicated airspeed of 280 knots.
3. Estimate the instantaneous fuel consumption for each flight condition given in parts (a) and (b).
4. Comment on the observed trends.