Assignment 4: Air Transportation Systems Analysis

Solution Instructor: Trani

Problem 1

Use the new generation Transonic Truss-braced Wing Aircraft (TTBW) file to answer this question (http://128.173.204.63/cee5614/cee5614_pub/TBTA_class.m). The TTBW is a NASA proposed aircraft concept reduce fuel burn using a high-aspect ratio wing (see Figure 1).

a) Estimate the **aircraft rate of climb** after departing Eagle County Regional Airport (EGE) while the aircraft **flies at 250 meters above the airport ground level and 180 knots indicated**. Assume atmospheric conditions are ISA. Assume the wing **flaps are fully retracted** and use the regular table lookup function to estimate *Cdo* provided in the aircraft file. The aircraft departs Denver with a mass of 68,000 kilograms.

EGE airport is located at 1996 meters above mean sea level conditions.

Aircraft state: 180 knots (IAS) and 2,246 meters above mean se a level conditions.

Indicated airspeed = 180 knots

Altitude = 2245 meters

Mass of aircraft = 68000 kilograms

Drag = 26008 Newtons

Thrust = 138758 Newtons

Fuel Burn = 18.039 N/s

Mach Number = 0.303 dimensionless

TAS = 100.57 m/s

ROC = 17 m/s

ROC = 3345.35 ft/min

b) Repeat part(a) if the aircraft suffers an engine failure at 250 meters while traveling at 180 knots indicated airspeed.

Change the value of n=2 to n=1 in the aircraft file.

Indicated airspeed = 180 knots

Altitude = 2245 meters

Mass of aircraft = 68000 kilograms

Drag = 26008 Newtons

Thrust = 69379 Newtons

Fuel Burn = 9.019 N/s

Mach Number = 0.303 dimensionless

TAS = 100.57 m/s

ROC = 6.54 m/s

ROC = 1286.83 ft/min

c) Can the aircraft fly the MEEKER Standard Instrument Departure (see page 60 of the course notes for Meeker One Departure) and meet the climb gradient required? Current departure is MEEKER three.

The minimum climb gradient to fly the departure is **815 feet per nautical mile**. The aircraft climbs at 100.57 m/s (330 ft/second). The climb gradient is:

Assume one engine fails:

TAS = 100.57 m/s

ROC = 6.54 m/s

ROC = 1286.83 ft/min

Climb Gradient = 394.94 ft per nm

The aircraft cannot achieve the climb gradient required by the procedure with one engine failed.

With two engines working:

TAS = 100.57 m/s

ROC = 17 m/s

ROC = 3345.35 ft/min

Climb Gradient = 1026.72 ft per nm

d) Compare the rates of climb obtained in parts (a-b). Comment on the implications of an engine out condition at 250 meters.

The rate of climb with one engine failed is 38% of the ROC with two engines working. The aircraft needs to operate at a lower mass and perhaps adjust the climb speed to satisfy the climb gradient required in the procedure.

e) Use the Unrestricted climb rate Matlab script to estimate the Top of Climb (TOC) for the TTBW aircraft concept if the pilot would like to maintain a 500 feet per minute climb potential at the TOC.

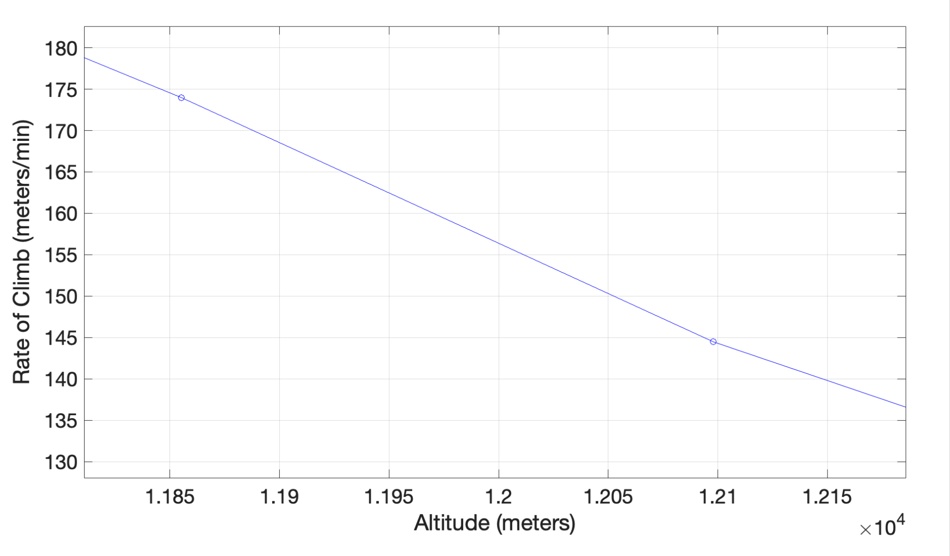

Figure 1.TTBW Rate of Climb Profile. For 152 m/min climb rate we can use FL390 as the initial cruise altitude.

The initial TOC can be FL390 to provide the 500 ft/min (152m/min) climb rate.

f) Find the fuel burn near the TOC if the pilot starts the cruise phase at Mach 0.73.

The aircraft reaches FL390 after burning 1002 kilograms in the climb profile. The TOC mass is 66,998 kilograms.

Indicated airspeed = 257 knots

Altitude = 11890 meters

Mass of aircraft = 66998 kilograms

Drag = 29915 Newtons

Thrust = 34910 Newtons

Fuel Burn = 4.538 N/s

Mach Number = 0.73 dimensionless

Problem 2

Use the new generation TTBW file provided to answer this question. The TTBW aircraft now operates out of Dubai with a mass of 69,000 kilograms at at ISA + 20 deg. C.

a) Run the **unrestricted climb Matlab code** demonstrated in class for the aircraft in question. Simulate the climb profile for 3600 seconds (one hour) and estimate the **time to climb** and distance traveled to reach FL 370 (37,000 feet).

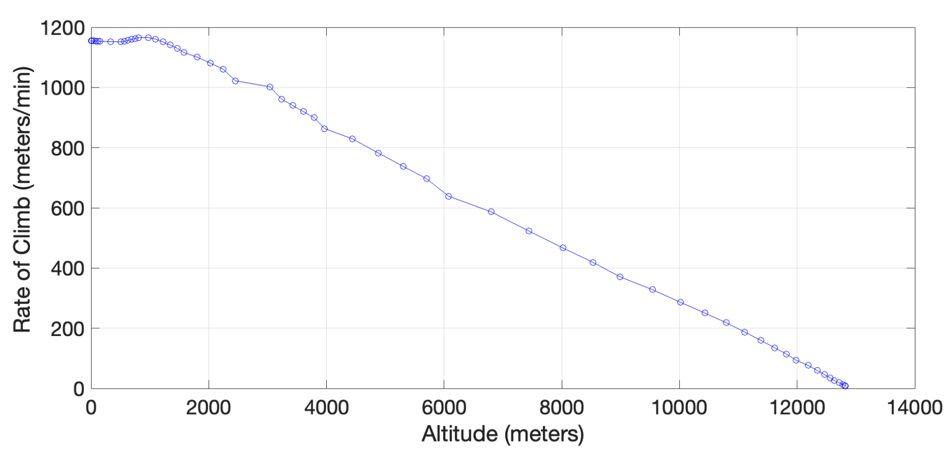

Figure 1.TTBW Rate of Climb Profile with ISA + 20 deg. C. Conditions.

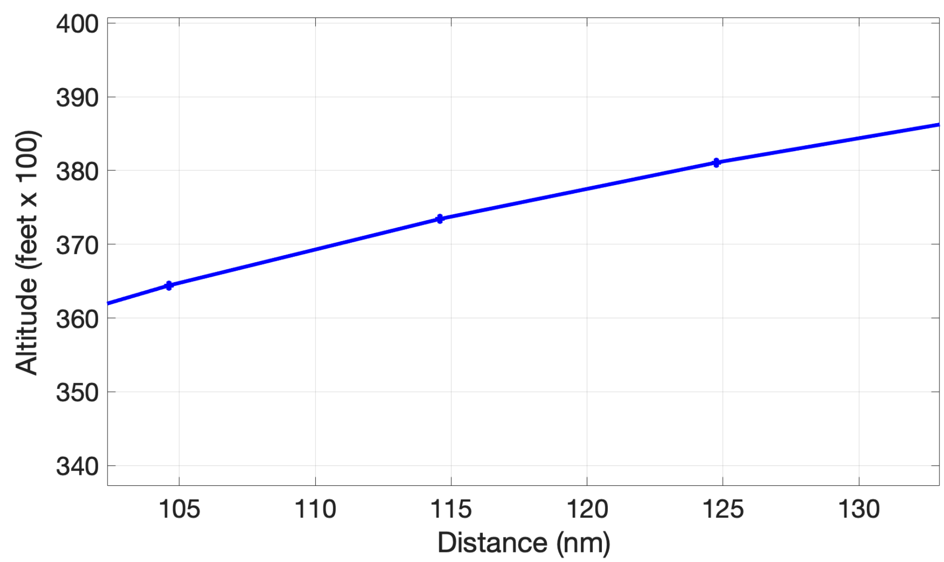

Figure 2. Climb ISA + 20 deg. C. Conditions. Aircraft Travels 111 nm to Reach FL 370.

b) Using the results obtained in part (a), estimate the fuel burned during the climb to reach FL 370.

Mass at FL370 is 67,831 kilograms. The aircraft burns 1169 kilograms.

c) Estimate the L/D ratio at the Top of Climb (TOC) as the aircraft starts its cruise phase at Mach 0.73.

Indicated airspeed = 269.5 knots

Altitude = 11280.4878 meters

Mass of aircraft = 67831 kilograms

Drag = 31765 Newtons

Thrust = 38516 Newtons

Fuel Burn = 5.007 N/s

Mach Number = 0.73 dimensionless

TAS = 215.4 m/s

L/D Ratio = 20.95 dim

d) On a hot summer day, the aircraft departs Dubai at ISA+30 deg. C. Run the computer simulation (similar to part a) using the same initial takeoff mass of 69,000 kilograms and estimate the time to climb, distance traveled, and fuel used to reach FL370. Compare the results obtained in parts (a-c) and comment on the effect of temperature on rate of climb and time to climb.

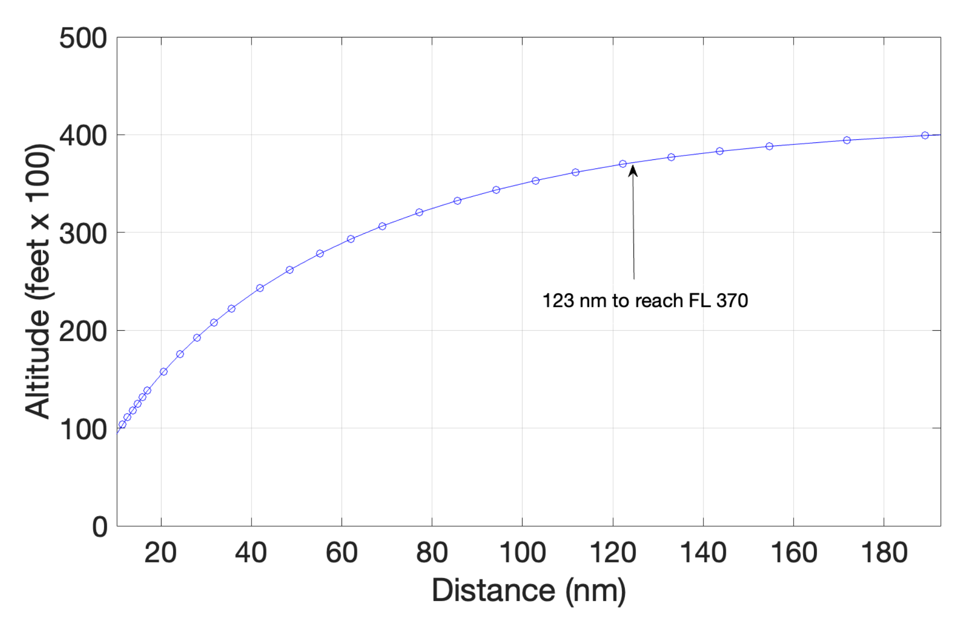

Figure 3. Climb ISA + 30 deg. C. Conditions. Aircraft Travels 123 nm to Reach FL 370.

Problem 3

Use the Boeing 787 class file (http://128.173.204.63/cee5614/cee5614_pub/B787_class.m) to answer the following questions

a) Estimate the value of Specific Air Range (SAR) for the aircraft while in cruise at Mach 0.84 and 36,000 feet. The mass is 200,000 kilograms.

Indicated airspeed = 321.3 knots

Altitude = 10975.6098 meters

Mass of aircraft = 200000 kilograms

Drag = 113623 Newtons

Thrust = 120306 Newtons

Fuel Burn = 17.384 N/s

Mach Number = 0.84 dimensionless

TAS = 248.03 m/s

L/D Ratio = 17.27 dim

SAR = 0.034 nm/lb

SAR = 0.14 km/kg

b) Repeat the process in part(a) after a long flight if the mass is now 175,000 kgs. Comment on the effect of aircraft mass on SAR.

Indicated airspeed = 321.3 knots

Altitude = 10975.6098 meters

Mass of aircraft = 175000 kilograms

Drag = 105673 Newtons

Thrust = 120306 Newtons

Fuel Burn = 16.168 N/s

Mach Number = 0.84 dimensionless

TAS = 248.03 m/s

L/D Ratio = 16.25 dim

SAR = 0.037 nm/lb

SAR = 0.151 km/kg

c) Use the Range equation, to estimate the maximum range for the aircraft if the aircraft reaches the TOC point (36,000 feet) at 200,000 kilograms. The aircraft cruises at Mach 0.84. The pilot estimates the aircraft carries 85,000 kilograms of fuel remaining at the TOC point. In the range calculation, assume the range is calculated using the aircraft mass at the mid-point between TOC and TOD. Also, assume that 6300 kilograms of fuel are needed in the descent plus a possible diversion to an alternate airport.

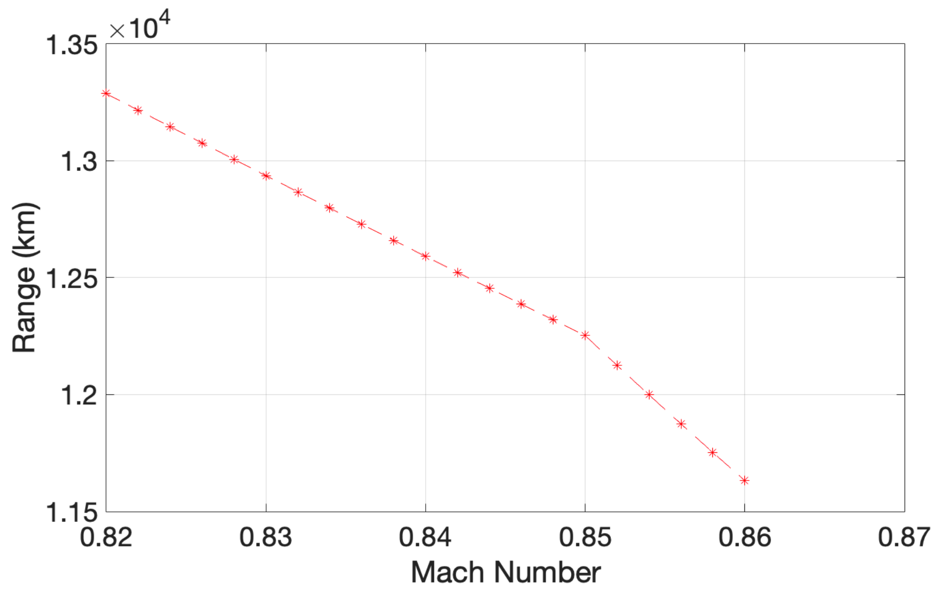

Figure 4. Range Analysis using Breguet Range Equation for Aircraft in Problem 3.

Range = 12,591 kilometers (6799 nm).

d) Solve the problem in part (c) using a piecewise numerical analysis method (as explained class). Use the range value obtained in part (b) and refine the answer obtained by dividing the range into six segments in the numerical solution. Comment on the obtained in parts (c) and (d).

Using six segments

Cruise Fuel (kg) 81562.0

Cruise Time (minutes) 846.5999

Initial Mass (kg) 200000

Final Mass (kg) 118437.9671

Average Fuel Burn (kg/min) 96.3407

Average SAR (nm/kg) 0.08336

Using 500 segments

Cruise Distance (nm) 6799

Cruise Fuel (kg) 80244.5

Cruise Time (minutes) 846.6

Initial Mass (kg) 200000

Final Mass (kg) 119755.45

Average Fuel Burn (kg/min) 94.78

Average SAR (nm/kg) 0.0847

Problem 4

Read the paper entitled: Development of an Efficient Mach=0.80 Transonic Truss- Braced Wing Aircraft article by Harrison et al. (AIAA year 2020) to get familiarized with the latest design procedures of the TTBW aircraft.

A) Explain the aerodynamic refinements made to the original SUGAR Phase III aircraft in order to improve the cruise speed of the TTBW.

B) What kind of L/D ratios are predicted for the Mach 0.8 TTBW and how they compare to the original SUGAR Phase III aircraft?

C) Wing flutter is a concern in high aspect ration wings. Does the paper addresses flutter margins?