Assignment 4: Air Transportation Systems Analysis

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Problem 1

The National Airspace System is a complex system with more than thirty thousand commercial flights each day. The file nasOperations_2011.xls contains a sample of the flights that were filed one day in the NAS. The header and a few flights are illustrated in Table 1. The Excel file contains a tab that explains each one of the columns of data (see Data Dictionary Tab).

Table 1. Sample NAS Flights File.

Flight ID	Aircraft Type	Type of Aircaft	Origin Airport	Destination Airport	Cruise Flight Level (feet/100)	Cruise Speed (knots)	Departure Time (hrs)	Arrival Time (hrs)	Distance Flown (nm)
BSK641	B738	J	MUHA	MIA	230	346	1.70	3.40	235.17
CSDKC	GLF5	J	OMA	DAL	190	337	13.83	16.15	586.62
EJA931	C750	J	FLL	APF	60	249	23.50	0.12	100.82
TSU132	CVLT	T	MDSD	BQN	150	279	23.63	0.40	166.49
ABX2217	B762	J	MIA	SPIM	340	471	22.78	4.55	2621.49
ABX2250	DC86	J	NGU	MUGM	320	450	12.13	15.20	1178.55
ABX2251	DC86	J	MUGM	NGU	380	453	17.18	20.77	1178.55
ABX38	B762	J	ZBAA	ANC	390	462	19.28	3.25	3950.40
AIP511	B190	T	HNL	MUE	130	219	11.30	12.32	171.82
AIP512	B190	T	MUE	HNL	120	219	12.63	13.65	171.82

a) Examine operations in the NAS performed by the Boeing 757 family aircraft (labeled as B757, B752, and B753 in the aircraft type column). Make a histogram of cruise flight levels assigned to the aircraft stated above. Explain the trends observed.

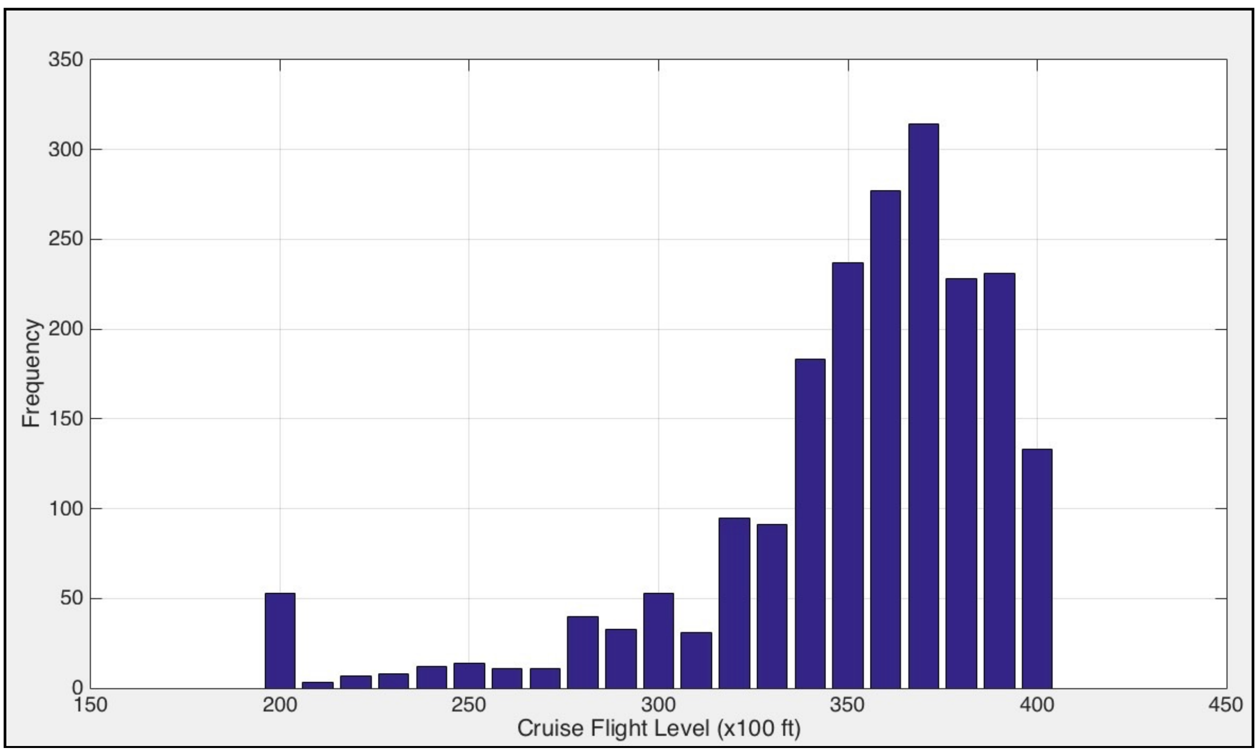

Figure: Histogram of Cruise Flight Levels for Boeing 757-200 and Boeing 757-300 Aircraft.

b) For the aircraft family in part (a), plot of stage length flown by the aircraft vs. frequency of operations. What is the mean and the mode of stage length for this aircraft?

The mean distance flown from the plot shown below is 1310 statute miles.

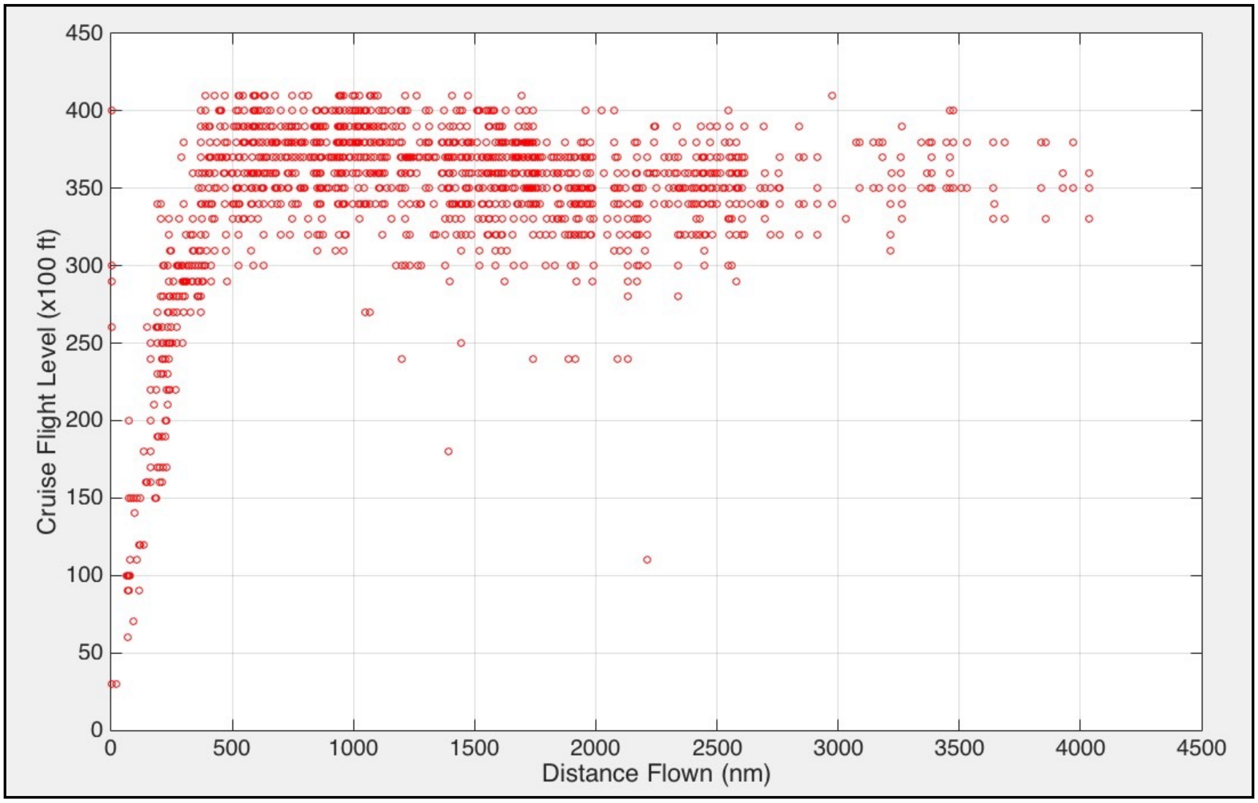

Figure: Distance Flown vs Cruise Flight Levels for Boeing 757-200 and Boeing 757-300 Aircraft.

c) Compare daily operations of B757 (all types) operated by American Airlines (AAL) and Delta Airlines (labeled as DAL and NWA in the flight ID column. Are the average stage lengths the same?

The average stage length for American is 1410 nm. The average stage length for Delta is 1159 nm. Both airlines have a different structure and hence the stage length are not the same.

Problem 2

a) For the medium size jet transport aircraft provided in the class web site (http://128.173.204.63/courses/cee5614/cee5614_pub/Boeing737800Jet_class.m), estimate the climb profile (distance vs. altitude) using the unrestrictedClimbAnalysis.m Matlab script. Run the program at different takeoff weights ranging from 50,000 to 75,000 kg (steps of 5 metric tons). Assume ISA conditions. Use the speed profiles provided in the same file.

Table: TOC Points for Medium Size Transport.

Takeoff Mass (kg)	TOC Altitude (meters)	TOC Altitude (feet)	TOC Rounded (feet)	Mass at TOC (kg)	Fuel to TOC (kg)	Distance (km)
50000	12,900	42,312	42,000	48,680	1,320	170
60000	11,873	38,945	38,000	58,440	1,560	172
70000	10,854	35,600	35,000	68,190	1,810	169
75000	10,213	33,500	33,000	73,100	1,900	163

b) Estimate the Top of Climb (TOC) point for each run made in part (a). Assume the pilot is comfortable cruising at a flight level where the climb rate is 150 m/minute. Plot the TOC altitude as a function of aircraft weight.

Shown in the previous table. It is clear that the fuel use increases as the mass of the vehicle increases.

c) How many kilograms of fuel does the aircraft burn in the climb profile departing Norfolk, VA airport at ISA conditions if the Desired Takeoff Weight (DTW) is 655 kiloNewtons? Estimate the TOC cruise flight level and also state the distance to climb to reach the TOC point.

The aircraft can climb to FL 360 of 36,000 feet. The aircraft will use 1709 kg of fuel to climb to FL360.

d) Using the solution found in part (c) what is the climb rate of the aircraft at flight level 270 (27,000 feet)?

The ROC is estimated to be 536 m/minute (1,760 feet/min) using the solution to the aircraft mass differential equation of motion.

Problem 3

Use the medium size jet transport aircraft to answer this question (http://128.173.204.63/courses/cee5614/cee5614_pub/Boeing737800Jet_class.m).

a) Estimate the rate of climb after the aircraft departs Mexico City International airport (say at a point 1,000 feet above the airport ground level). Assume the aircraft has takeoff flaps of 5 degrees which add 0.005 to the draft coefficient. The aircraft departs Mexico City airport with a mass of 63,000 kilograms. The indicated airspeed at the point of interest is 210 knots.

We start the analysis as the aircraft climbs through 8,320 feet (1,000 feet above the airport elevation of 7320 feet). Modify the velocity table and the Cdo tables in the aircraft file as shown below.

```
% Drag characterictics - CDO function (zero lift
% drag function)

Cdoct   = [0.0175  0.0175  0.018  0.022  0.038] + 0.005;
macht   = [0.0  0.70 0.78 0.82 0.85];
```

Figure : Drag characteristics of of medium size transport aircraft with flaps down. Note the additional drag Cdo factor in the Cdoct vector.

```
% Computes the aircraft climb and descent profiles given altitude (VCAS given) - typical for
% a tyical 150 seat transport aircraft

Vclimb = [210 210 210 210 230 230];          % knots indicated (near optiimum for ROC)
%Vclimb = [180 195 222 230 230];              % knots indicated
Vdescent = [200 220 230 240 240 210];        % knots indicated
altc = [ 0 1000 3000 4000 6000 14000];       % meters
```

Figure : Velocity profile for controlling climb of medium size transport aircraft.

The result of the trajectory of this aircraft is shown below. The plot of ROC vs. altitude indicates that the aircraft with two engines (all engines) climbs at 1,300 meters/min initially.

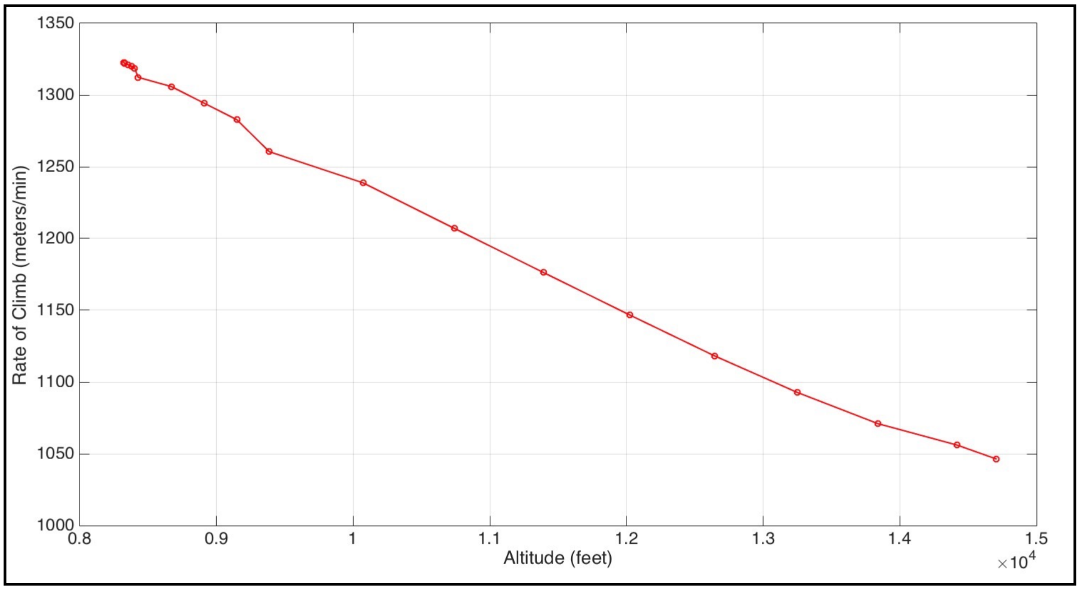

Figure : Rate of Climb Profile for Medium Size Transport Aircraft. Initial Mass is 63,000 kgs.

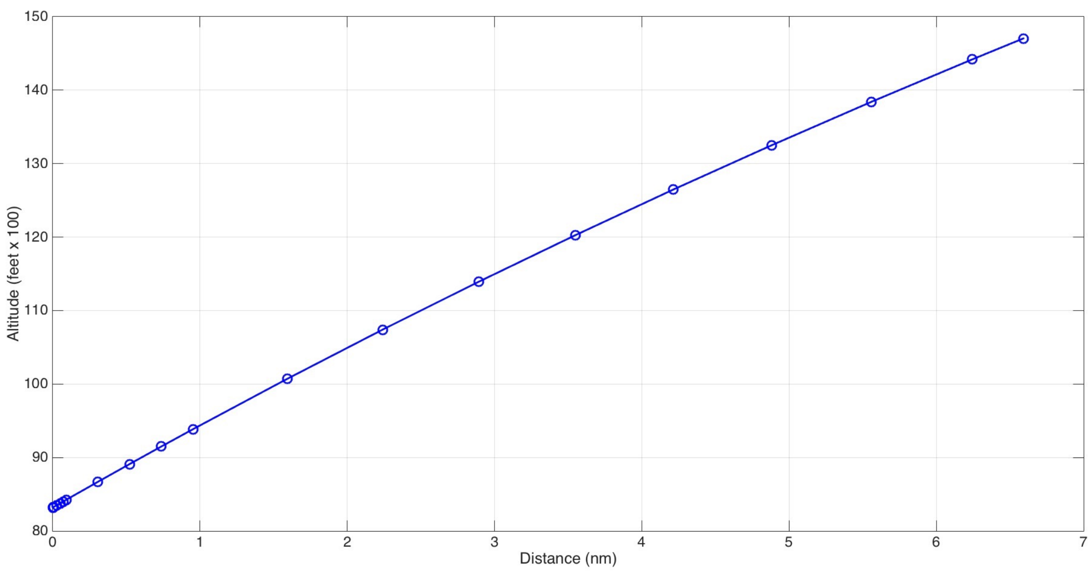

Figure : Climb Profile for Medium Size Transport Aircraft. All Engines Working and Initial Mass is 63,000 kgs.

b) Repeat the process now simulating an engine failure at the same point in the climb profile. Compare the rates of climb obtained in pats (a) and (b).

We now simulate an engine failure and let **n=1** (number of engines) in the **master aircraft file**. The result of the trajectory of this aircraft is shown below. The plot of ROC vs. altitude indicates that the aircraft with one engine climbs at 435 meters/min initially. This is far less than 1,300 m/min observed with all engines operating.

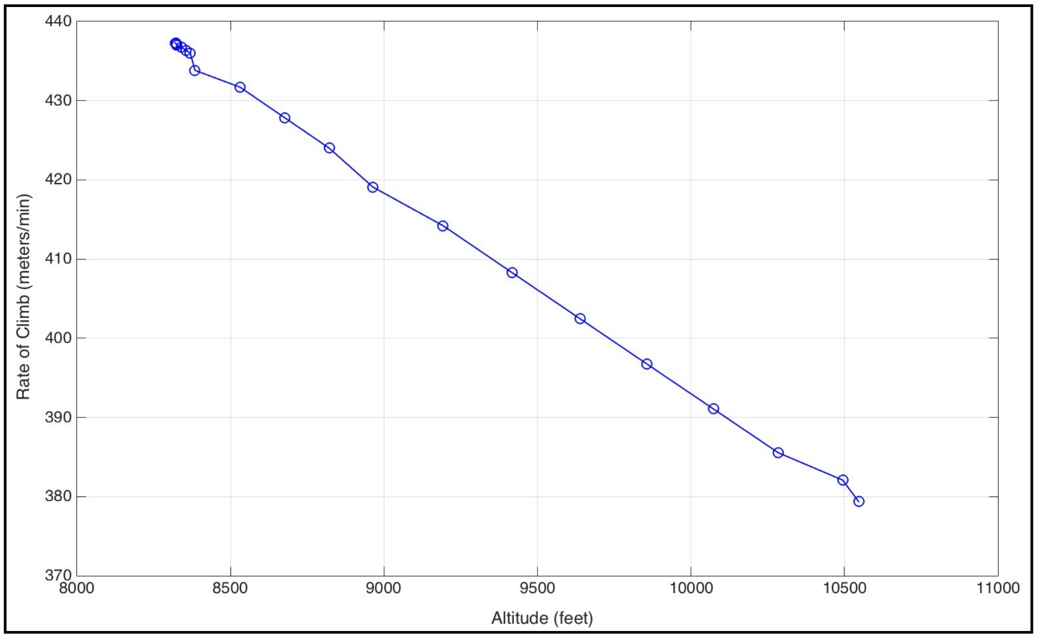

Figure : Rate of Climb Profile for Medium Size Transport Aircraft. ***Engine Out Condition*** *and Initial Mass is 63,000 kgs.*

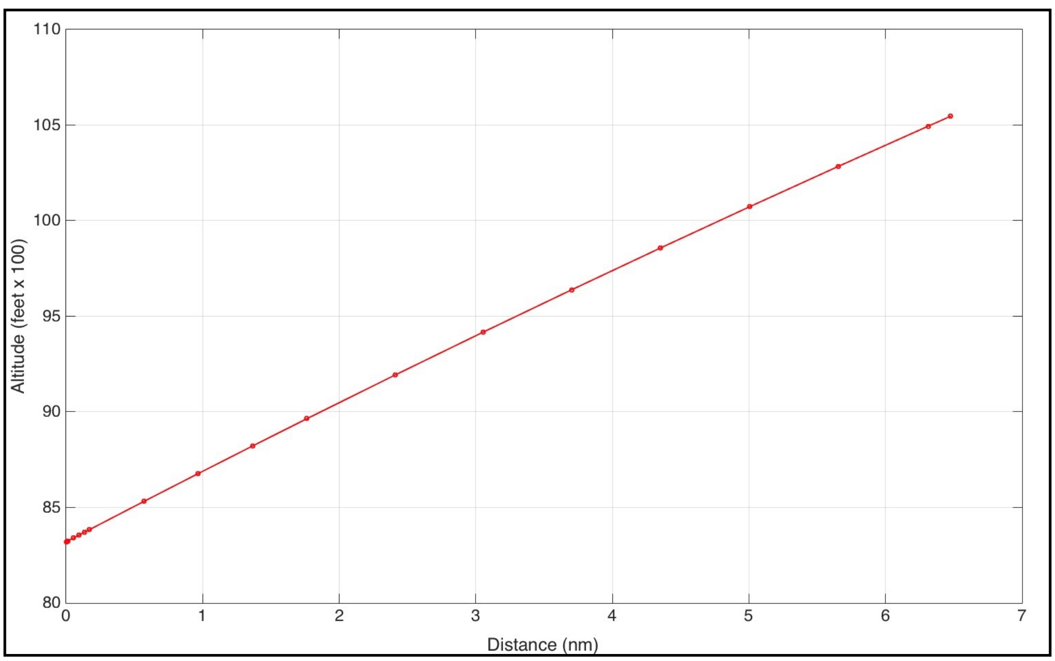

Figure : Climb Profile for Medium Size Transport Aircraft. ***Engine Out Condition*** *and Initial Mass is 63,000 kgs.*

c) Will the aircraft be able to clear a 3,500 meter mountain located 6.0 nm from point of engine failure? The minimum clearance vertical distance is 300 meters.

The aircraft reaches 10,300 feet (3,110 meters) above sea level at a point 6 nm from the engine failure. Note that this is below the 3,800 meters required for clearance. This implies that this operation is restricted due to a climb limitation requirement in the climb segment of the trajectory. The airline will have to modify the climb procedure or reduce aircraft weight to satisfy the required climb gradient. One aspect to avoid obstacles is off course turning to avoid the, However, in high elevation airport like Mexico City, many obstacles need to be investigated and an optimal path needs to be developed to plan for engine out conditions.

Note: You can solve this problem using hand calculations instead of computer simulation.