Assignment 4: Air Transportation Systems Analysis

Solution   Instructor: Trani

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 Aircraft	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 Airbus A320 family aircraft (labeled as A318, A319, A320 and A321 in the aircraft type column). Make a plot of cruise flight levels assigned to the aircraft stated above vs. the distance flown. Explain the trends observed. What is the average cruise altitude used by these aircraft in all routes?

We observe that as the distance flown increases, the aircraft can reach higher cruise flight levels. The patterns seems to stop at around 500 nm as shown below.
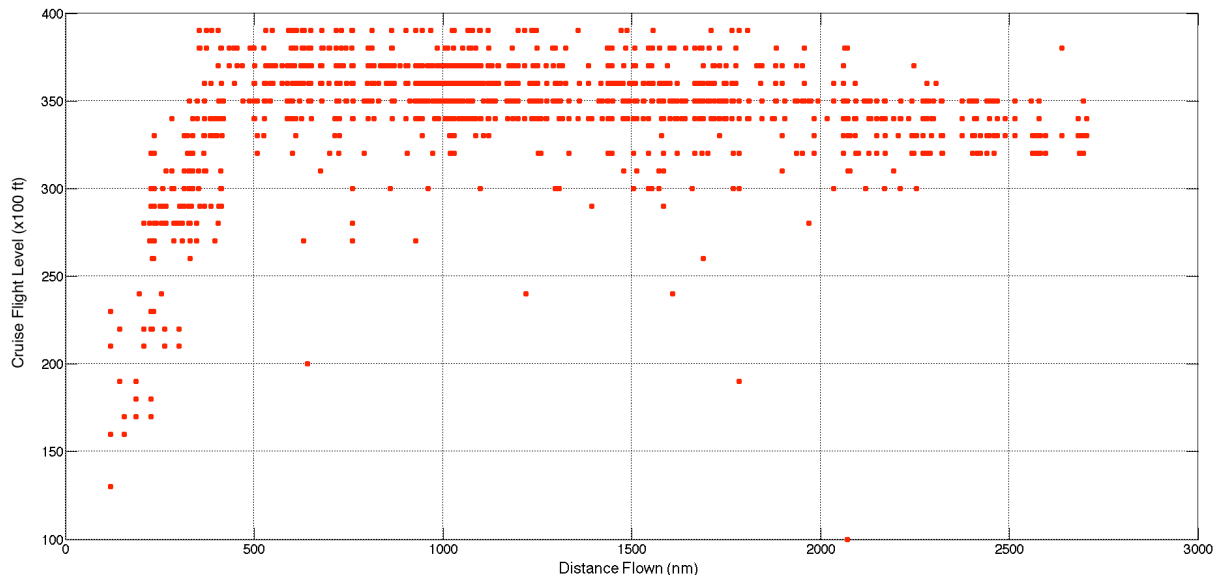
Figure 1. Distance Flown vs Cruise Flight Level. Airbus A320 Aircraft Only.

b) b) For the aircraft fund in Part (a), create a histogram representing the stage length flown by the aircraft vs. frequency of operations. What is the average stage length flown by A320 family aircraft?
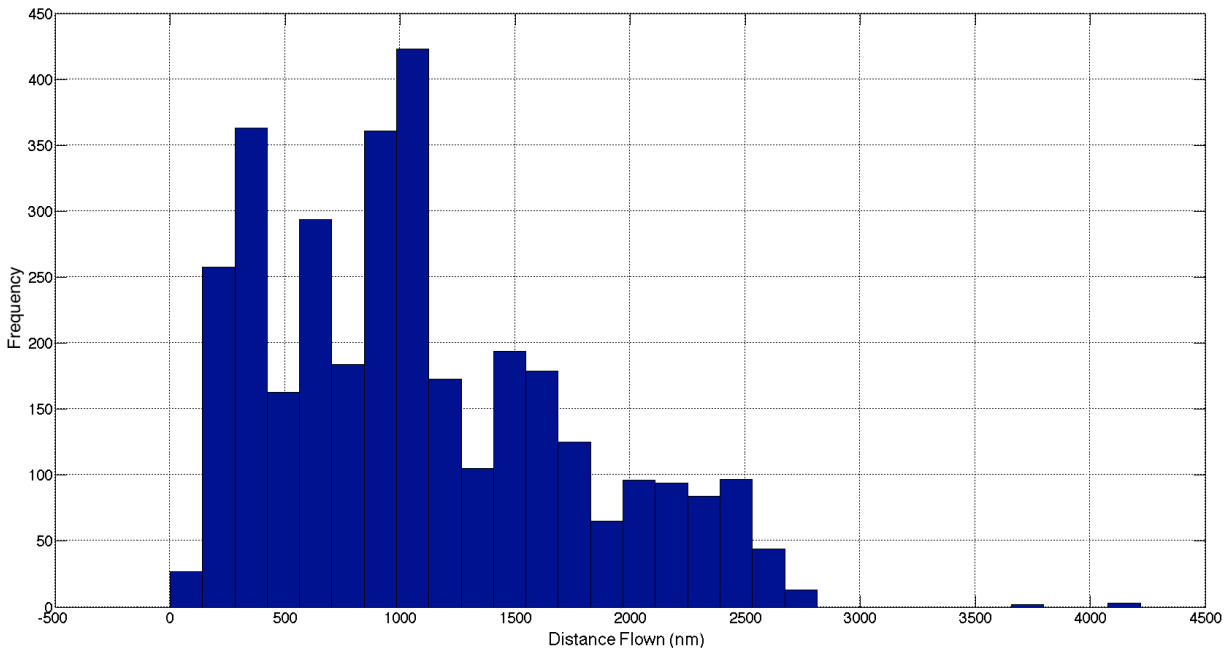

Figure 2. Histogram of Distances Flown by Airbus A320 Family Aircraft. Average Stage Length is 1087 nm.

c) Compare daily operations of Jetblue Airlines (flight ID starts with JBU) Airbus A320 and those of USAirways (flight ID starts with AWE) in the NAS. Contrast the distribution of the stage lengths flown (i.e., distance flown) and the cruise flight levels and filed cruise speeds used.

Jetblue achieves a higher average distance with A320 aircraft. This reflect its network structure with many flights performing intercontinental flights and flights to the Caribbean.

d) Explain any difference observed in the stage lengths flown by each type of Airbus aircraft in part (a). For example, are A321s operated differently than A319 and A320 aircraft? Comment.

A321 aircraft are used in longer routes thus they average 1350 nm per flight. The Airbus A318 has the shortest stage length at 860 nm. The average stage length for the Airbus A320 is monotonically increasing from the A318 to the A321.

Problem 2

a) For the large twin-engine, long-range transport aircraft provided in the class web site (http://128.173.204.63/courses/cee5614/cee5614_pub/boeing777_class_2006.m), estimate climb profile (distance vs. altitude) using the unrestrictedClimbAnalysis.m Matlab script. Run the program at different takeoff weights ranging from 280,000 to 340,000 kg (steps of 20 metric tons). Assume ISA conditions. Comment about the changes observed in distance and time to climb to cruise flights levels where the aircraft is still able to climb at a slow pace (i.e., 400 feet/min).

Mass at Takeoff (kg)	Time to Climb (min)	Distance to Climb (km)	Altitude to 400 ft/min
340,000	20	228	10,970 meters
280,000	16	195	11,750 meters

b) How many metric tons of fuel does the aircraft burn in the climb profile departing San Diego International Airport at ISA + 20, DTW of 310,000 kg? The pilot files 350 as the initial cruise flight level at TOC.

The aircraft takes 195 km to reach FL350. The aircraft burns 11,690 kilograms of fuel.

c) What is the climb rate of the aircraft at flight level 350 (35,000 feet)?

155 meters/min at 35,000 feet.

d) Find the distance traveled in the climb to 35,000 feet.

195 km to reach FL 350.

e) Perform a manual calculation to estimate the climb rate for this aircraft as it passes 3,000 meters at 230 knots Indicated Airspeed (IAS). Assume ISA conditions in this calculation.

Problem 3

a) For the large twin-engine, long-range transport aircraft provided in the class web site (http://128.173.204.63/courses/cee5614/cee5614_pub/boeing777_class_2006.m), estimate the **fuel used in cruise** from the TOC point found in Problem 2 until the aircraft starts its descent to Narita (RJAA) airport in Tokyo (a point located 140 nm from the Narita airport). Here are some assumptions for this flight.

    a. DTW = 310,000 kg (per Problem 2)

    b. Fuel onboard = 120,000 kg

    c. Passenger Load = 30,000 kg

    d. Cargo load in LD3 containers = 20,000 kg

    e. OEW = 140,000 kg

    f. Planned route distance = 5,100 nm (includes possible ATC and weather detours)

    g. Cruise altitude = 35,000 feet (ISA conditions in cruise)

    h. Cruise speed is Mach 0.82

    In this analysis consider a minimum of 5 segments to calculate the fuel burned in the cruise profile.

Under ISA conditions, the aircraft covers 109 nm to climb to FL 350. The aircraft burns 10.35 metric tons of fuel to reach TOC. At the TOC, the aircraft has a mass of 299,650 kilograms (310 metric tons at takeoff). Using recursive calculations in cruise and 5 intervals we find:

    Cruise Fuel = 75,504 kg

    Cruise Time = 509 minutes

    Cruise Distance = 4000 nm

Using 50 steps instead we have:

Cruise Fuel = 74,158 kg

Cruise Time (minutes) 509 min.

Cruise Distance 4000 nm

b) Is the amount of fuel carried sufficient to fly the route SAN-RJAA? Comment.

Yes there is plenty. In fact the aircraft carries 40 metric tons of fuel beyond that needed. That is more than the required fuel reserve.

c) Find the distance traveled to the TOD (Top of descent point) and also the travel time from takeoff to TOD.

The distance to the TOD point (from origin airport) is 4109 nm.

d) Compare the fuel burn estimated in part (a) with a more optimal profile where the aircraft climbs to 37,000 feet after flying 3 hours at 35,000 feet. How much fuel is saved?

In 3 hours flying at 471.8 knots, the aircraft covers 1,415 nm. The fuel burned in 3 hours from TOC is 28,076 kg. (used 50 segments in cruise). 2,585 nm remain in the cruise mode. The aircraft would have a mass of 271,570 kg at the point where it starts its climb to FL370.

Fuel used in climb is:

15 nm to climb from FL350 to 370 (I used the unrestricted climb file). The aircraft climbs at 300 meters/min. Remaining cruise distance is 2,570 nm.

120 seconds to climb 2,000 feet.

Aircraft burns 365 kilograms in the climb to FL 370. At start of FL 370 cruise the aircraft has a mass of 271,050 kg.

Fuel used at FL370 is:

44,876 kilograms

Comparing the fuel used:

FL350 = 74,158 kg

FL350 and FL 370 = 73,317 kg (includes cruise at FL 350, climb to FL 370 and cruise at FL 370)

The aircraft is more efficient flying at FL370. It saves 841 kilograms.

e) Using the Breguet range equation and using 135 metric tons of usable fuel, estimate the maximum range the aircraft can fly in cruise mode at Mach 0.82 and 36,000 feet.