Assignment 7: ETOPS Operations and Runway Capacity

Date Due: October 28, 2013 Instructor: Trani

Problem 1

A new generation large twin engine aircraft with performance similar to the Boeing Dreamliner (http://128.173.204.63/courses/cee5614/cee5614_pub/boeing787_class.m) flies the route Lagos (LOS), Nigeria to Houston (IAH), Texas. The route requires ETOPS certification because most of the flight crosses the Atlantic Ocean (see Figure 1). Assume the aircraft is flying at Mach 0.82 and 37,000 feet with a mass of 175,000 kg when one of the engines is shut down in flight due to a malfunction. At the time of the engine failure, the aircraft is located 760 nm from Miami, Florida and 715 nm form Bermuda. Assume no wind and ISA conditions.

a) Estimate the best Mach number and cruise altitude to continue to any one of the alternate airports. Justify your selection based on the single engine capability of the aircraft and also considering the flight to the closest alternate. In your solution consider that the aircraft requires some excess thrust for maneuvering under single engine conditions.
b) Find the fuel consumed if the pilot decides to go to land in Miami.
c) If the aircraft suffers a pressurization failure instead, explain how would you do the analysis in part (b).

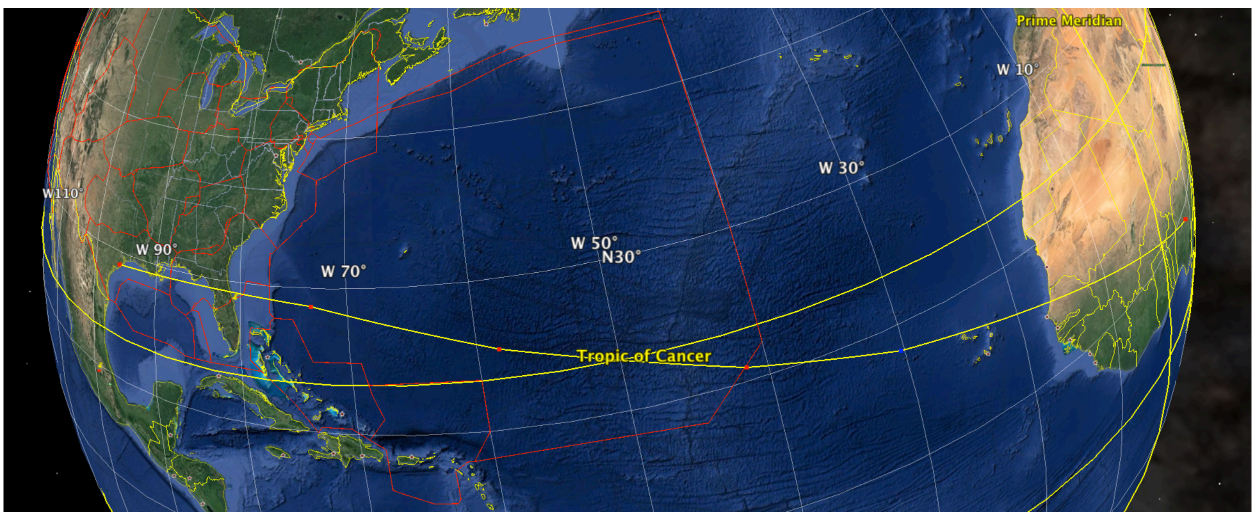

Figure 1. Lagos (LOS), Nigeria to Houston (IAH), Texas Flight Plan. Source Map: Google Earth.

Problem 2

You are expected to perform a simple capacity analysis for the Mexico City International Airport (ICAO code MMMX) considering both theoretical and real operational limitations. The MMMX airport layout is shown in Figure 2 in the Google satellite picture. The airport has two parallel runways spaced 1,000 feet between runway centerlines. Typically, runway 05R is used for arrival and 05L for departures. The airport is surrounded by terrain and requires that all arrivals be channeled through a single Final Approach Fix (SMO VOR) as shown in Figure 3. The navigation chart showing the ILS approach to Mexico City Runway 5R is shown in Figure 4.

The MMMX airport has a standard airport surveillance radar (ASR) which tracks aircraft up to 60 miles form the airport site. The radar has a scan rate of 4.5 seconds. Table 1 shows the approximate fleet mix operating at the airport. For this analysis we use the following technical parameters: a) in-trail delivery error of 18 seconds (position delivery error at SMO VOR) under both VMC and IMC conditions, b) departure-arrival separation for IMC conditions is 3.0 nautical miles (when mixed operations are conducted on the same runway), c) probability of violation is 5%. Arriving aircraft are “vectored” by ATC to the final approach fix located 15.7 miles from the runway threshold (see Figure 3). Arrivals follow in-trail after crossing the final approach fix (SMO VOR). The airport aircraft mix, runway occupancy times and approach speeds are shown in Table 1. The typical IMC separation values applied by ATC are shown in Table 2 and Figure 5.

Figure 2. Mexico City International Airport Layout. Source: Google Earth 2013. Runways 5R and 5L are separated 1,000 feet. Runway 5R is used for arrivals and 5L for departures.

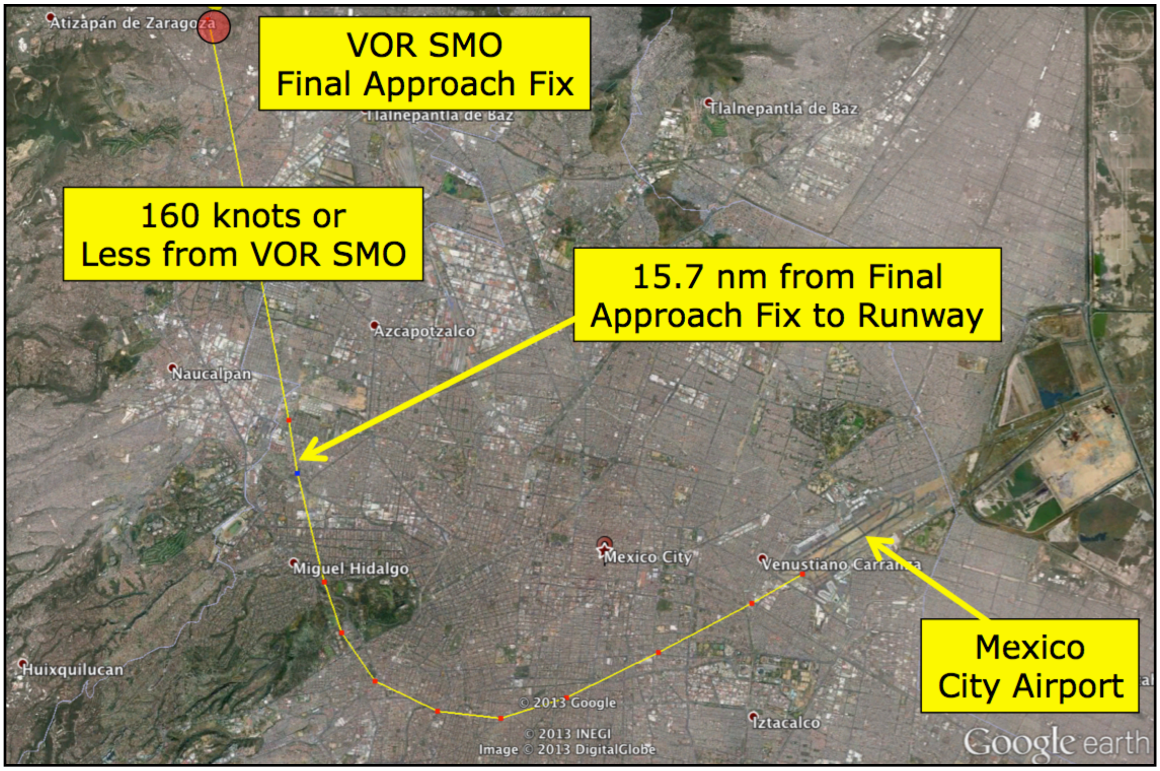

Figure 3. Google Earth View of Approaches to Runway 5R at Mexico City International Airport. Source: Google Earth 2013. Note: all aircraft arriving to runway 5R intercept the San Mateo VOR (NAVAID used as final approach fix).

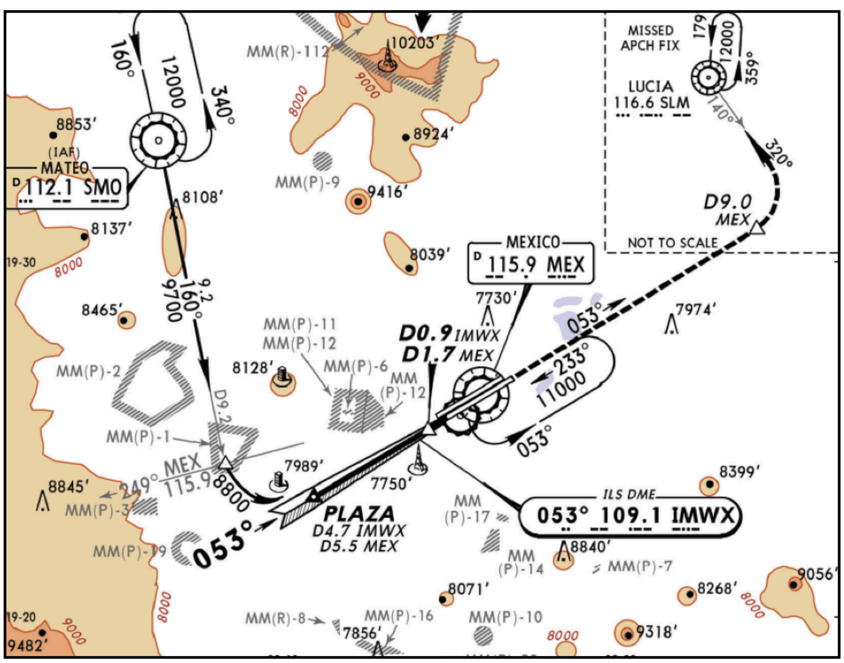

Figure 4. Instrument Landing System Approach Procedure Runway 5R at Mexico City International Airport. Source: Jeppesen 2013.

Table 1. Runway Operational Parameters and Fleet Mix for Problem 1.

Aircraft	Percent Mix (%)	Runway Occupancy Time (s)	Typical Approach Speed (knots) from FAF
Small	5	45	125
Large	70	57	145
Heavy	20	65	152
SuperHeavy	2	85	150

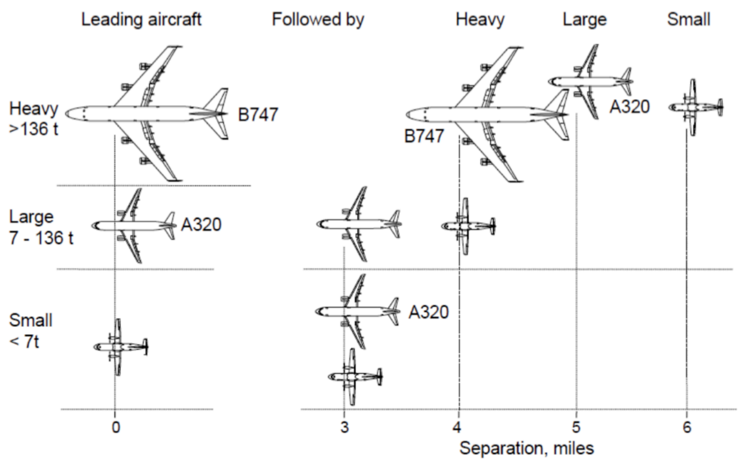

Figure 5. ICAO Recommended IMC Separations. Source: Lang et al., 2010. Arrival-Arrival Separations for all Groups Behind a Super-heavy add 2 nm over the Heavy Category.

Table 2. Minimum Departure-Departure Separations under IMC conditions. Values in are seconds.

Departure-Departure Separation Matrix (seconds)					
	Trailing Aircraft (Header Columns)				
Lead (column 1)	Small	Large	B757	Heavy	Superheavy
Small	60	60	60	60	60
Large	90	60	60	60	60
B757	120	120	60	60	60
Heavy	120	120	120	120	90
Superheavy	150	120	120	120	120

Estimation of Runway Capacity Operations

a) Find the IMC arrival saturation capacity of the runway configuration shown in Figure 2 when only runway 05R is used for arrivals.

b) Find the IMC saturation departure capacity with 100% arrival priority of the airport if we assume departures operations are dependent of the arrivals calculated in part (a) with only runway 05L used to handle departures. The operational concept used by ATC at MMMX airport is shown in Figure 6 and can be described as follows: The primary arrival runway is runway 05R. Runway 05L is used to handle departures. ATC controllers provide arrival with priority and reserve the short final approach zone (~1.4 nm) so that no departure can be released if the arriving aircraft is inside that zone. This situation is to avoid a possible go-around of an arriving aircraft while at the same time processing a departure on 05L. In such situation, the two aircraft will be flying too close due to the runway separation. Assume the arriving aircraft fly at the average approach speeds provided in Table 1.

c) Plot the Pareto diagram (arrivals/departures diagram) for using the solutions (a) and (b).

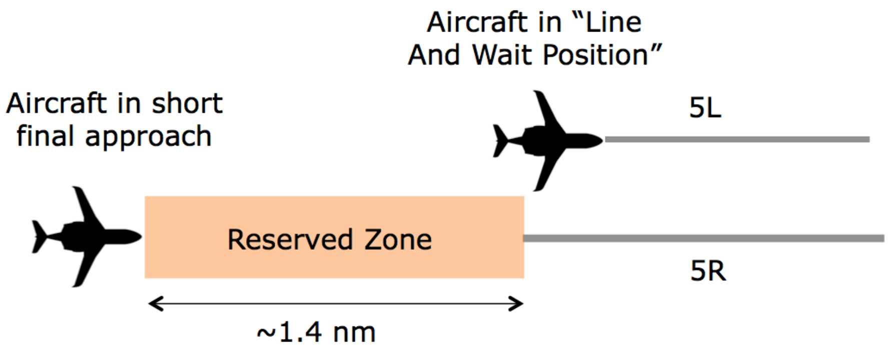

Figure 6. MMMX Airport Operational Concept.

Problem 3

Read a section of the Propulsion Chapter of Whitford's book (Pages 97-123) and answer the following questions briefly (2-3 sentences).

a) Turboprop aircraft such as the Vickers Viscount and Vickers Vanguard were introduced in the early 1950's (Viscount) and in the 1960's (Vanguard). Explain why these turboprop had limited success even though they were more fuel efficient than turbojet powered aircraft of the time.

b) Some of the largest commercial airliners introduced by US companies (Boeing and Douglas) used an under-the-wing pod mount configuration. Explain the advantages and disadvantages of such configuration.

c) Name two successful American aircraft that had under-the-wing pod mount configuration.

d) Most of current turbofan engines used in commercial aircraft have 2 or 3 shafts linking the engine compressor with the engine turbines. Explain the advantages of a multi-shaft turbofan engine configuration.

e) Some of the most successful turbofan engines such as the CFM56 (used in the Airbus A320 and Boeing 737 families) and the GE90-90 have large by-pass ratios (6.6 and 8.4, respectively). Explain why a high by-pass ratio is desirable in modern engines.

f) Compare the in-flight shutdown (IFSD) rate requirements for 120 and 180 minute ETOPS operations (called EROPS operations in Great Britain and in the book). If an airline pilot flies and average of 1,000 hours per year, what is the likelihood that a pilot will be involved in an actual IFSD event?