Assignment 5: Air Transportation Systems Analysis

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Problem 1

On a busy day, Chicago O'Hare Terminal Radar Approach Control (TRACON) instructs a few aircraft to fly holding patterns over Lake Michigan. The typical holding patterns is flown as a 4-minute maneuver with one minute per side and one minute in the 180-degree turns (see Figure 1). On a busy day, the controller instructs a pilot flying a long-range wide-body aircraft (like the Boeing 787 class vehicle provided in the class notes) to fly the pattern at 12,000 feet and 240 knots (IAS).

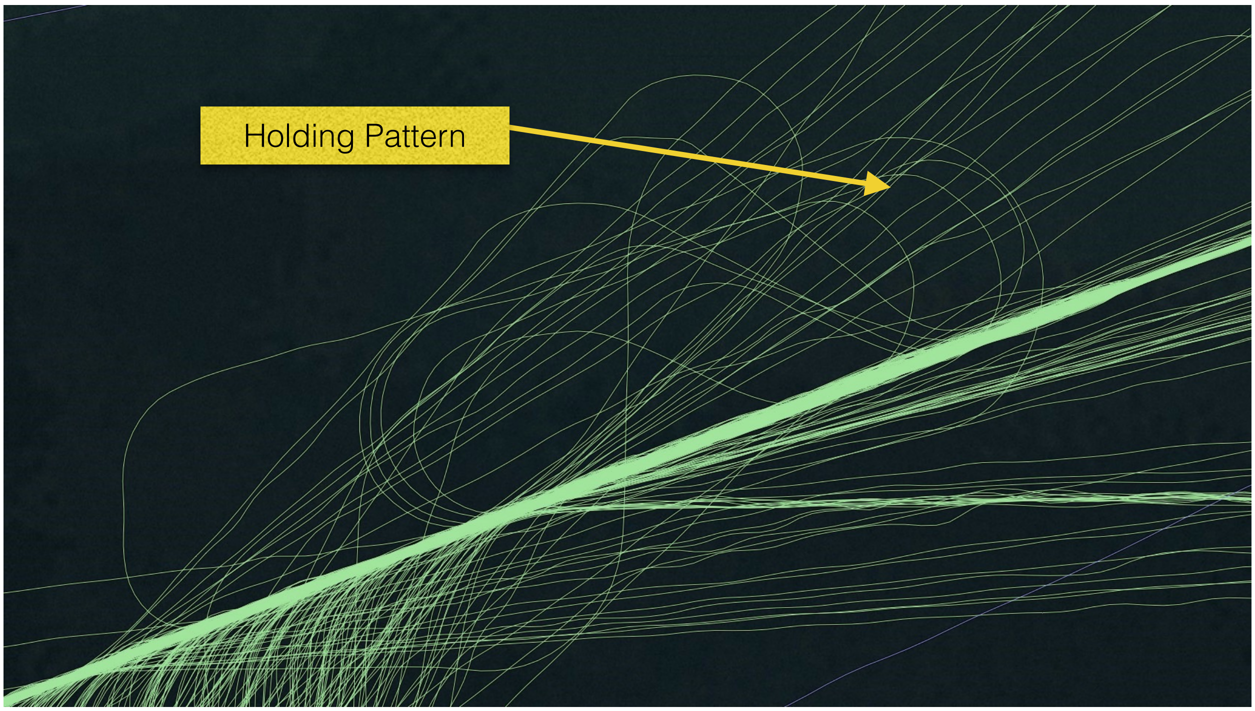

Figure 1. Holding Patterns over Lake Michigan.

a) Estimate the fuel burn consumed in one 4-minute holding pattern for the aircraft in question.

b) Estimate the how much engine thrust is needed in both the straight and the turning segments of the holding pattern.

Step 1: Estimate the mass of the aircraft

The problem requires that we estimate the drag characteristics in both level and turning flight. The mass of the aircraft is not specified so I would use the Maximum Allowable Landing Mass since the aircraft is holding while approach to land. For the Boeing 787 class aircraft, the value of MALW is then made up of OEW, the maximum payload and add another 10000 kg of fuel. We estimate the value of landing weight to be 171,000 kg.

Step 2: Find the atmospheric parameters

At 12,000 feet and 240 IAS the following parameters are found: a) true Mach number = 0.433, speed of sound = 325.98 m/s, density of air = 0.845 kg/cu.m.

Step 3: Find the lift coefficient needed to maintain flight

a) Wings level condition

Cl = 0.67, Cd = 0.032, D = 104,706 N

b) Turning flight

Cl = 0.84, Cd = 0.042, D = 136,416 N

The fuel used in each segment is:

The fuel used in each level segment is 961.20 N

The fuel used in each turning segment is 1252.31 N

The total fuel used per holding pattern is **451 kg. of fuel.**

c) Find the radius of the turn for the aircraft flying the holding pattern.

R = 2,696 meters (8,843 feet)

d) What is the bank angle (in degrees) to fly the holding pattern?

The bank angle is 0.65 radians (37 degrees). This angle exceeds the maximum bank angle used in airline operations (30 degrees).

Problem 2

Read Chapter 1 of the Instrument Procedures Handbook (http://www.faa.gov/regulations_policies/handbooks_manuals/aviation/instrument_procedures_handbook/). Briefly answer the following:

a) How many types of departure Procedures exist? In two sentences explain each one.

Obstacle Departure Procedures (ODPs)

A procedure designed to insure appropriate clearance over obstacles around an airport. Typically the Requires Obstacle Clearance is 1000 feet in non-mountainous areas and 2,000 feet in mountainous terrain.

Standard Instrument Departures (SIDs)

An ATC-requested and developed departure route designed to increase capacity and efficiency in the terminal area around busy airport. SIDs are designed so that once a pilot is assigned the SID, the complete route inside the terminal area is know to both pilot and ATC controllers.

b) Explain the difference between actual and Net Flight Paths. Refer to Figure 1-19 in the Handbook.

Actual (or Gross) OEI flight path represents the vertical One-Engine-Inoperative (OEI) climb profile that the airplane has been demonstrated capable of achieving using takeoff procedures developed for line operations based on the airplane's weight, configuration, and environmental conditions at the time of takeoff.

The OEI net takeoff flight path represents a degraded gross OEI flight path by an amount specified by the certification rules to provide a safety margin for expected variations under operational conditions.

c) What is the typical RNP in the enroute and terminal airspace today in the NAS?

RNP2 for enroute. RNP1 for terminal airspace.

Problem 3

To do this problem, use the Boeing 737800 class aircraft file from the web site (http://128.173.204.63/courses/cee5614/cee5614_pub/Boeing737800Jet_class.m).

a) Use the unrestrictedClimbAnalysis.m Matlab script to estimate the mass of the aircraft at the Top of Climb (TOC) point. The aircraft takeoff weight is 76,000 kg. with 20,000 kg of fuel. Use the default climb speed profile provided in the aircraft data file. Use ISA atmospheric conditions in your calculations. The departure airport is located at sea level conditions. Select the TOC altitude so that the aircraft has an initial 500 ft/min climb capability.

The aircraft TOC is estimated to be 33,000 feet (rounded to the nearest flight level).

b) Use the unrestrictedDescendAnalysis.m Matlab script to estimate the fuel used from the Top of Descent (TOD) point (say at 33,000 feet) to the destination airport. The destination airport is located at sea level conditions (assume ISA conditions in the decent as well). In this calculation assume the mass at the TOD point is 60,000 kg.

The aircraft final mass is 59,446 kg. The fuel used is 553.8 kilograms.

c) Use the Breguet range equation, find the still-air (no wind) range of the aircraft with the parameters provided in parts (a) and (b) with the aircraft flying at 33,000 feet and Mach 0.78. To calculate the range parameter use the mass of the aircraft at a mid-point between TOC and TOD points.

The mid-point mass is 68,000 kg. This mass is used to estimate the aerodynamic parameters (Cl and Cd). The Range equation is:

$$R = \frac{V}{TSFC} \frac{L}{D} \ln\left(\frac{W_i}{W_f}\right)$$

$$R = \frac{V}{TSFC} \frac{C_l}{C_d} \ln\left(\frac{W_{TOC}}{W_{TOD}}\right)$$

V = 233.4 m/s (Mach 0.78 at 33,000 feet). TSFC = 0.000190 (N/s / Newton). Climb fuel is 1.861 metric tons. The mass at the top of the climb is 74,139 kg. Assume the top of the descent point is 60,000 kg.

At the mid-point (mass = 68,000 kg), the aerodynamic parameters are:

Drag = 39,170 N

L/D = 17.03

Range = 4,427 kilometers