Comparison of some simulated and actual CDA trajectories

Plus comments on validity and prediction accuracy
Goal

• Build a simulation capability for CDA descents of commercial aircraft (TOD to TRACON entry)
• Determine accuracy of CDA descent predictions to determine reasonable spacing & delay requirements for time-based scheduling for high density CDA/non-CDA traffic
  – Determine delayability requirements to achieve required spacing at entry to TRACON
Simulations

• Matlab code developed to fly constant CAS/Mach descent trajectories
  – Concentrate on idle thrust descent trajectory from TOD to Meter fix altitude
  – Trajectory options: a) constant CAS/Mach; b) constant FPA; c) constant CAS & FPA (variable thrust/drag)

• Use BADA database of aircraft information to generate trajectories

• Simulation allows for variable winds, non-standard temperature, as well as choice of weight, descent CAS/Mach

• I choose to end my simulations at 11kft to omit consideration of decel segments

• The goal is to determine the accuracy with which we can compute CDA descent times- important for scheduling
BADA data- comments

• Data defines “nominal” aircraft aerodynamics, weight, thrust, speeds

• Some aero data seems very inconsistent.
  – E.g. L/D)max = 15.4 (757-300); 19.1 (767-200); 17.7 (767-400). What is correct? (Changes descent time by 3 minutes) (Note: Airbus data similarly inconsistent!)

• “Nominal” cruise aero lacks Mach dependency- probably important for high speed descent

• Reference descent speeds too slow (typ 280->340)

• Idle thrust is small but some data has discontinuities
Some sample simulation runs
Comments on simulations

- BADA data sets available for most aircraft – but not all engine combinations
- Nominal “cruise” aerodynamics used for descents. No mach dependency
- Nominal speeds available (cruise; descent;..) but actual data is quite different
- Use “descent” thrust

- Constant winds affect descent distance- but not time
- Altitude variation in winds affects both time and distance
- Descent very sensitive to assumed aerodynamic model and descent speed
- Less sensitive to weight
Descent data

• Tailored arrivals SFO
  – B777, B747
  – X,y,z,Vg data. No wind, weight
  – Initial altitude 17-25 kft

• CDA at SDF
  – DFDR data
  – Data from before TOD to runway
SFO 747 TA

Descent profile (all ac)  Typical ground track

7/31/2009
Sample SFO results

- Short data range makes comparisons difficult
- Lack of weight detracts from comparisons
- Choose selected flights with relative smooth CAS descent
- Assume $V_{ground} = TAS$. Data shows significant CAS variation during descent for most aircraft

B747 data (SFO) 280kt descent
SDF data

• Two weeks data: B757, B767 ac
• DFDR has CAS, Vg, Wind info in addition to x,y,z, ...
• Data goes from before TOD to runway (typically 35-40kft)
• To compare data to sim, truncate DFDR data at 11kft
CAS/mach variation often not smooth see CAS- example 767 data

Variable CAS/Mach 340/.82 descent

Note: Convert CAS to TAS/Mach using standard atmos model
Some of the data fits very well- Best case times here accurate to a few seconds!

7/31/2009
767-200 data; W= 250-270klb

Typical descent 340/.82

Using original BADA data
- 767-200 drag too low
  - (L/Dmax=19.1!)
- Distance error ≈10-15nm
- Time error ≈ 60-90 sec

Switch to BADA 767-400 polar
Repeat 767-200 w/modified drag

- Use BADA drag model for 767-400
  - CDp=.014-.0173
  - L/Dmax= 19.1 -17.7
- Distances from TOD much improved
- Time error (from TOD) ±20sec
Winds can affect the data. See sample data below. Try to resolve wind information to improve descent calculations.

We model winds using piecewise linear model. Effect of winds seems to be minimized by FMS?
DFDR flight data

• We assume constant CAS/Mach is aim—Actual FMS operation seems quite different
• Actual CAS/Mach on descent can be very erratic
  – Only a few descents have a consistent smooth speed variation! Makes accurate prediction very difficult.
Observed descent speeds

757

767
For any particular ac it can be difficult to pick a descent mach/speed profile- Strong effect on descent calculations

Calculated decent time for different assumed descent speeds. (Actual time – 537 sec)

Recorded CAS-Mach descent profile for one case
Weight and descent speeds major factors in descent time. Winds and non-standard temperature are not

SDF - 757 Week 2

Week2 767

Assumed CAS/M for descent calculations vary based on observed data (typ 320-335 kts)
Week1 757

Week1 767
Overall statistics (36 ac)

• Choose “best” speed & weight
  – Average error = -19sec (Max error ≈100sec)

• Add wind estimate (post priori data)
  – Average error -13 sec (Max error ≈100sec)

• Add temperature data
  – Average error -32 sec
Summary

• BADA database OK for general studies- but need more accurate data for realistic scheduling

• Need more data to determine if UPS descent data is representative of “normal” commercial traffic (based on SFO data– NO)

• Based on UPS results, typical accuracy of descent prediction is on the order of 30sec. (note errors typically < 0 --with a few very bad cases) Better aero model might help remove bias.
Summary (2)

• For most flights, it was difficult to choose a “constant CAS/Mach” descent. Adding wind info helped time predictions slightly. Temperature data did not help
  – Related to FMS control algorithm?

• Descent distances are also important- but were not part of this analysis. (Typical errors in distance: 3-7 nm)

• More data?
Questions?
A distance error plot - 757

Week 1 B757, 33kft cruise

Week 1 B757, 37kft cruise

Distance error plot - 757