RNAV/CDA Arrival Design
2004 Flight Test Trials
Louisville International Airport

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JPDO EIPT Operations Panel
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Overview

• Profile Design
• Pre-Test Simulator/Flight Testing
• Arrival Chart/Flight Crew Procedure Design
• Results
• Lessons Learned
• 2006 CDA Plan
Profile Design

Horizontal Profile
- Utilize existing arrival/waypoints
- Minimize flight distance
- Flyable by FMS/Auto flight system
- Stay outside of restricted area

Vertical Profile
- FMS capabilities
- Usable by different FMSs
- Keep auto flight system in VNAV
- Minimize flight crew workload
- Minimize flight crew procedural changes

Air Traffic Coordination
- How to handle clearance-route and descent
- Minimize change to current procedures
CDA Flight Tracks

[Diagram showing flight tracks with various waypoints and coordinates.]
Simulator Testing

- B-757 FMS-200K Basic/B-767 FMS-Pegasus 2001
- Tested profiles up to 80 knot tailwinds
  - With and without pre-programming winds in FMS
- Route programming
  - Tests done without database
  - Required manual waypoint/constraint entry
- LNAV issues
  - When to select localizer and approach mode
- VNAV issues
  - Speed intervene use
  - When to configure aircraft
  - Making profile get underneath glide slope
Flight Testing

• Test flown in B-767-300
• ATC Coordination
• Manually loaded CDA waypoints/constraints
  – Lead to unexpected results with pre-loaded database
• Validated simulator testing
• Flight test results required altitude constraint modification
Air Traffic Coordination

Flight Plan Filing
- Flights filed for ‘non-CDA’ STAR
- Crews would load CDA STAR

Indianapolis Center
- Established a greater in-trail spacing
- Changed descent clearance at ‘CHERI’ waypoint
- Requested early frequency change to ‘Louisville Approach’

Louisville Approach Control
- Provides CDA clearance to 17R or 35L
- Provides pilot discretion descent clearance
- Cleared flight crew for ILS approach
Arrival Chart/Procedure Design and Implementation

Arrival plate design
- Displayed arrivals to both runways
- Standardize crew procedures
- Abbreviated flight crew procedures/techniques

Flight crew procedures
- Arrival designed with FMS limitations in mind
- Limit speed brake use
- Approach intercept procedures easy to execute

Implementation
- Issued as a Jeppesen special plate
- Loaded in FMS navigation database
Jeppessen Arrival Chart

VERTICAL NAVIGATION PLANNING INFORMATION

Arrival must be flown using FMS LNAV and VNAV guidance.

ARRIVAL:

PILOT NOTES
1. KSFDF ATIS will indicate if CDA procedures are in effect for UPS B767/777 arrivals.
2. Load the CDA17R or CDA35L with the filed transition and the corresponding ILS. Close the discontinuity between the arrival and the ILS final approach fix.
3. Verify speed/altitude constraints from the FMS match the Jeppessen CDA chart.
4. Set FMS descent speed to 820 KIAS.
5. MCP altitude window should be set to lowest assigned ATC altitude clearance. The 38000 ft altitude at the TRN17/35 waypoints is not an ATC restriction but initiates the speed slowdown.
6. Enter any ATC speed or route changes in the FMS and use power or speed brakes to re-acquire the VNAV path. Flight level change of vertical speed should not be required.
7. For best VNAV path performance maintain speed close to commanded speed.
8. Select FLAPS to 1 no later than FLP17/F35 and FLAPS to 5 prior to TRN17/TRN35.
9. Arm APPROACH after receiving ATC clearance for the ILS.
10. After goes slope capture, set speed window to match CDA profile.
11. No later than 1 mile prior to final approach fix, select gear down and FLAPS 20.

Results

FMS Issues
• Some crews had to manually load procedure
• Sequence of loading deleted altitude/airspeed constraints

Flight Issues
• Excessive use of speed brakes
• Intercept of glide slope prior to localizer capture
• Required attention to VNAV commanded speeds

ATC Issues
• Clearance for ILS occurred earlier than normal

Modifications to procedures
• Loading sequence
• Approach clearance
• Sent winds to aircraft

So! How did we do?
CDA Versus Standard Flight Tracks

Ground Track to SDF 35L

- Latitude, deg.
- Longitude, deg.

- ZARDA
- PENTO
- SACKO
- CHERI
- RWY35L
- CRDNL
- CRD27
- FLP35T
- TAN35

- Black line: B767 CDA on Sep 22
- Blue dash line: B757 CDA on Sep 15
- Black solid line: B767 STD on Sep 08
- Blue dash line: B757 STD on Sep 28

11
CDA Versus Standard Vertical Profile

Vertical Profile to SDF 35L

- **B767 CDA on Sep 22**
- **B757 CDA on Sep 15**
- **B767 STD on Sep 08**
- **B757 STD on Sep 28**

Altitude, 1000 ft

Distance Flown, nm

-140 -120 -100 -80 -60 -40 -20 0
CDA Versus Standard Engine RPM

AVERAGE Engine N1 to SDF 35L

- Distance to Runway, nm
- Average N1, %

Graph showing the comparison between CDA and Standard Engine RPM with data points for different locations and days.
Time Comparison

104 / 90 sec reduction from CHERI
Fuel Usage Comparison

- 465 / 279 lb reduction from CHERI

![Fuel Usage Comparison Diagram]

Mean with Standard Error

- B767 STD
- B767 CDA
- B757 STD
- B757 CDA
### Theoretical Fuel and Cost Savings - Annual

<table>
<thead>
<tr>
<th></th>
<th>B-757 279 lbs/flt*</th>
<th>B-767 465 lbs/flt*</th>
<th>Total Fuel Savings</th>
<th>Total Annual Dollar Savings</th>
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</thead>
<tbody>
<tr>
<td>West Coast Arrivals 12-13 Aircraft/Night</td>
<td>49,800 Gallons</td>
<td>111,740 Gallons</td>
<td>161,540 Gallons</td>
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<tr>
<td>Next Day Air Outbounds 80%</td>
<td>201,250 Gallons</td>
<td>186,444 Gallons</td>
<td>387,694 Gallons</td>
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<tr>
<td>Total</td>
<td>251,050 Gallons</td>
<td>298,184 Gallons</td>
<td>549,234 Gallons</td>
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</tbody>
</table>
Noise Footprint

CDA Test (2 Weeks)
Baseline (3 Weeks)

% Reduction in Noise Contour Area

Change in Area, %

767-300s 757-200s 757PW 757RR

CDA
up to 33% reduction
Noise Exposure - CDA (Sep 14-Sep 18)
Noise Exposure - Baseline (Sep 28-Oct 2)
Noise Levels
Emissions

Bar charts showing emissions of HC, NOx, and CO for Baseline and CDA for two types of aircraft, 767 and 757.
Lessons Learned

We have to do this
  • Saves fuel and time
  • Reduces noise and emissions
  • Win-win

Arrival plate design
  • Applicable to all fleets
  • Minimize pilot notes, if any
  • Simplify

FMS procedures
  • Design arrival with FMS limitations in mind
  • Limit speed brake use
  • Intercept procedures easy to execute
  • Simplify/standardize wind uplink

Air Traffic Control
  • Vectors occurred further west
  • Reduced controller workload at Indy Center and Louisville Approach
  • Traffic flow is manageable at West Coast inbound rates
  • Mixed equipage may cause less than optimum CDA
  • FAA approval process can be slow
2006 Plan

Implement CDA arrivals for West Coast inbounds
• May be applicable to all aircraft types
• Dual stream arrivals to airport

Implement CDA arrivals to Next Day Air outbounds
• Target low density traffic gateways
Prerequisites To Implement

Arrival Design

• Requires additional simulator testing
• Requires lateral/vertical analysis for different aircraft types
  – NASA Langley

Approval Process

• UPS is lead for all coordination
• Must be submitted to POI for approval
  – 18 step FAA process recommended
  – Must be coordinated with FAA ATC
  – Could be lengthy
• Special UPS arrival
• May require training and/or operations bulletins
Questions?