DEVELOPMENT OF CONTINUOUS DESCENT APPROACH CONCEPTS FOR NOISE ABATEMENT

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Summary

One major problem for airports today is the noise and environmental effects of conventional aircraft approach procedures. Conventional approach procedures, for example, often descend aircraft to intermediate altitudes on the order of 2000 to 3000 feet, before transitioning onto the final approach path and final descent to the approach runway. The effect of such procedures is to spread noise and aircraft emissions onto nearby communities, sometimes as far away as 30 nm from the runway threshold. Continuous Descent Approach (CDA) procedures have been proposed to reduce noise and emissions by (1) delaying descent below 7000 feet as late as possible, and (2) descending at idle or near idle thrust from about 220 knots until final approach speed is reached.

This paper describes near-term, mid-term, and advanced operational concepts for FMS based CDA system deployments. The near-term CDA procedures focus on using existing FMS capabilities and Air Traffic ground automation systems to achieve noise reductions for night-time and light traffic operations when throughput is not an issue. The intermediate or mid-term CDA concept blends current RNAV concepts for terminal arrivals with minimum changes in airborne systems and moderate changes in ground automation systems to achieve high throughput traffic flows consisting of both conventional and FMS/CDA aircraft. The advanced CDA concept summarized below would require more substantial changes to airborne automation systems and use of air-ground data link to coordinate trajectory clearances for fully automated procedures for reduced noise approach transition and glide-slope capture.

Introduction

Considerable research and development of low noise approaches has established the potential value of CDA procedures. Earlier simulation studies [1] have shown that the potential noise reduction for a heavy turbojet of a continuous idle descent from 7000 ft altitude to about 2000 ft is on the order of 6 DBA average noise reduction compared to that of a conventional approach with 2000 ft intermediate altitude prior to glide-slope capture. CDA procedures are now flown regularly at London Heathrow using conventional altitude and speed clearances and manual autopilot parameter selections [2]. These manual procedures are workload intensive and occasionally result in undesirable vertical profiles, e.g. a level off at intermediate altitude may be required.

In order to reduce pilot and controller workload, FMS based CDA procedures are currently used at Amsterdam (Schiphol) and elsewhere to reduce noise during nighttime operations. The current FMS procedures require substantially greater separations than for peak operations, however, due to uncertainty in the velocity profile and time of arrival at an appropriate Final Approach Fix (FAF) [3]. Research continues in this area, in order to develop an advanced CDA procedure which achieves the noise reduction benefit of an idle descent, but yields predictable vertical and speed profiles so that traffic can be maintained at high throughput rates during daily peak operations, as well as for night-time and low density operations.

The main objectives of the Boeing CDA research reported here were to obtain a significant reduction in noise compared with conventional intermediate altitude approaches, and to examine feasibility of high throughput flow comparable to conventional procedures. The methodology investigated has been to make the lateral, vertical and airspeed profile of the aircraft highly predictable during the CDA procedure, from about 7000 feet until the Final Approach Fix (FAF) or Outer Marker (OM) is reached. Early simulation results obtained with a high fidelity simulation of a 737-700 aircraft showed that neither a conventional

3 deg FMS vertical path nor a 4 degree FMS flight path angle with idle thrust profile, followed by a transition to a 3 deg glide-slope on ILS worked very well for meeting both objectives. The main problem with 3-degree approaches was the difficulty in decelerating at an adequate rate starting at 7000 ft altitude and 220 knots airspeed. The problem at 4 degrees descent angle was even worse, and various flight trials have shown that kind of approach is generally objectionable due to need to deploy extra drag, i.e. speed brakes or early flaps.

Most of our investigations to date have focused on overcoming the problems found in the early studies. Recent research studies, described in a companion paper, have concentrated on solving the energy management and control issues associated with CDA approaches [4]. These studies have established that it is feasible for an advanced FMS aircraft to:

(1) Plan a vertical path profile from CDA top-of-descent to the FAF such that the airspeed profile follows a known, predictable deceleration from an initial airspeed on the order of 220 knots to a desired final approach speed,

(2) Execute vertical path control via an FMS based Path-on-Elevator command mode which assures that the planned vertical profile is in fact achieved, so that arrival at the FAF is at the right altitude for transition to the ILS Glide-slope, i.e. Glide-slope capture is assured with high probability, and

(3) Provide energy management flap advisories to the crew for achieving the desired airspeed profile, and providing path, speed and energy cues for pilot loop closure in achieving the desired flight objectives in the presence of unknown winds and other error sources.

In the next section of this paper we describe a current near-term activity to demonstrate CDA noise abatement at Louisville, using several UPS 767 airplanes flying special CDA procedures. The following sections then describe the current vision for evolving the CDA concept to an intermediate term system capable of high throughput operations in a mixed traffic environment, and the evolution of an advanced FMS/CDA system utilizing trajectory data link to integrate the operation of the ATC automation system and the airborne automation system for reduced pilot and controller workload.

Louisville CDA Preliminary Design

A near term demonstration of the CDA concept for noise abatement is currently in development for potential future use at Louisville during nighttime operations. This demonstration project is a joint collaboration of MIT, NASA, Boeing, UPS, the Louisville Regional Airport Authority and the Louisville TRACON. The material below summarizes the current CDA preliminary design, which will be refined and validated by analysis and simulations in progress.

Figure 1 shows the lateral routing selected to avoid noise sensitive areas until close to the final approach intercept point at BLGRS. The figure also shows the location of previous noise complaint sites when flying conventional approach procedures to runway 17R, i.e. for south flows to Louisville.

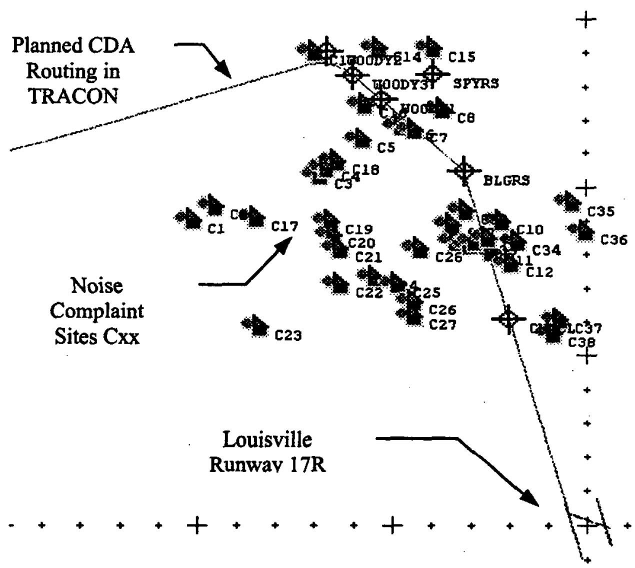

Figure 1. Lateral Routing for Louisville CDA Demonstration

This routing will require selection of a new waypoint in the navigation database near SPYRS. The new waypoint, designated WODY3, is the preferred Fly-By point for turning from the inbound path to intercept the final approach corridor at BLGRS.

The demonstration is being planned to fly two 767 aircraft on the above routing near the end of the UPS nighttime arrival rush over a two week test period. One aircraft will fly a CDA vertical profile from 7000 ft MSL, and the other will fly a conventional profile with a 3500 ft MSL level-off prior to glideslope capture, in order to evaluate noise benefit of the CDA profile. Two locations below the flight path are being instrumented to measure peak noise during the test periods.

Figure 2 shows the vertical profiles under analysis for CDA demonstration and the conventional vertical profile for comparison. Three flight path angles (FPA) for CDA descent were selected for initial study, i.e. 2.0, 2.5, and 3.0 degrees. The 2 deg FPA begins descent earliest, at about 26 nm from the runway threshold. All three profiles intercept a 3-degree glideslope at the same point as the conventional profile, at about 9 nm from the runway threshold.

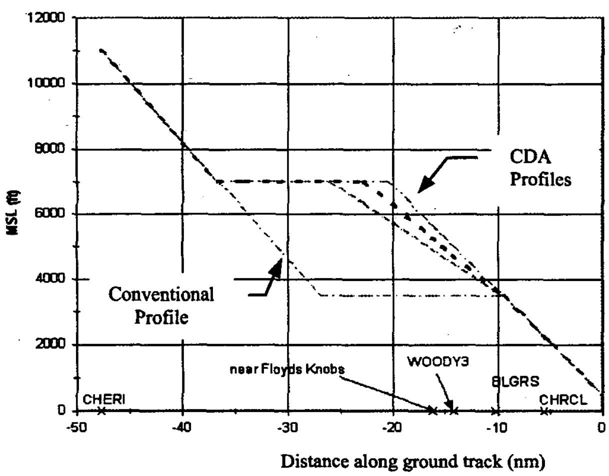

Figure 2. Louisville Approach Vertical Profiles

In addition to the above, a planned airspeed profile is needed for the CDA procedure. We assumed a conventional airspeed profile as a series of speed reductions from entry into the TRACON until final approach speed is attained near the threshold. Figure 3 shows the vertical profile, airspeed profile, and recommended 767 flap values to maintain the desired airspeed targets with a 2.5-degree FPA descent. It is assumed that the 767 aircraft enter the TRACON at 250 knots, reduce speed to 210 knots and deploy 1 deg flaps during the intermediate level-off at 7000 ft MSL, and then reduce speed to 180 knots at flaps 5 during the constant FPA descent, prior to the turn at WODY3. This target speed is then maintained until after glide-slope capture, when landing gear and landing flaps are deployed for the final descent segment following CHRCL.

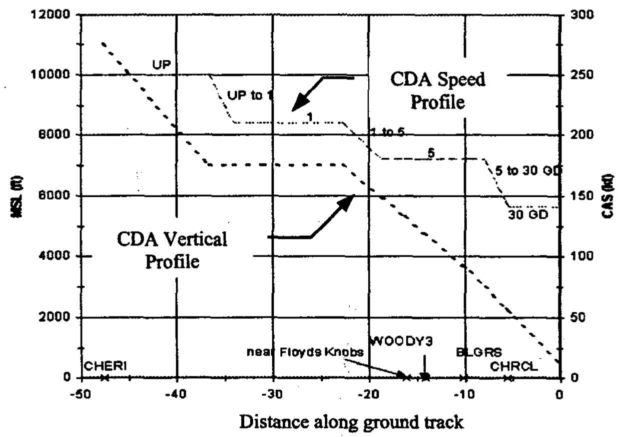

Figure 3. Vertical and Speed Profiles for 2.5 Deg FPA CDA Descent

The key issues for choosing an appropriate FPA for a public CDA procedure at Louisville are:

- Capability to decelerate from 210 knots to 180 knots (or lower) during the constant FPA descent phase,
- Minimization of the Noise Profile, especially in the vicinity of WODY3, and
- Pilot and Controller workload, i.e. reducing or maintaining workload at current tasking levels.

The 3-degree FPA descent has the best noise profile, but has minimal capability for speed deceleration. Moreover, pilot workload is likely to be an issue, especially with less capable FMS systems such as older model 757 aircraft flying into Louisville, since the pilot may need to manually dial in vertical speeds to fly CDA descents. Consequently, this option was quickly dismissed as not viable for the CDA demonstration. The 2.5-degree FPA descent has less than 1 DBA increase in noise profile compared to the 3-degree FPA, but has a marginal deceleration rate, i.e. < 0.4 knots /sec, even in a no wind case. (See Table 1, below.) On the other hand, the 2-degree FPA has acceptable deceleration capability, but has almost 2 DBA more noise than the 3-degree FPA profile. Thus, our recommended choice for the CDA demonstration is the 2.5-degree FPA descent. However, the 767 speed / flaps profile shown in Figure 3 may need to be modified to ensure sufficient deceleration capability during descent.

Table 1. Deceleration and Noise Comparisons for Four Descent Profiles (No Wind)

Descent Profiles	B757 Decel.[1] Kt/sec	B767 Decel.[1] Kt/sec	B757 Peak[2] DBA	B767 Peak[2] DBA
Conventional/ level segment	-	-	65.0	68.3
2.0 FPA / GS	0.51	0.47	58.3	61.8
2.5 FPA / GS	0.34	0.31	57.4	60.9
3.0 FPA / GS	0.17	0.14	56.5	60.1

Intermediate Term CDA Concept

The main objective of the intermediate term CDA concept is to enable merging of FMS/CDA and conventional traffic without significant loss of traffic throughput during peak arrival periods. This objective is to be achieved with minimum investment in advanced technologies, however, in order to lower technical risk, and in order to demonstrate feasibility of such operations.

In recent years, several airports worldwide have begun merging RNAV aircraft and conventional traffic during daily operations. (RNAV aircraft only provide horizontal path routing and guidance, whereas full FMS aircraft provide both lateral (LNAV) and vertical (VNAV) guidance for flight path management.) Our Intermediate CDA Concept builds on the RNAV operational concepts developed to date, but extends these concepts to include vertical profile management as well. In order to reduce investment costs to users, the implementation of intermediate CDA should not require pilot /controller data-link or other advanced CNS technologies, other than those which are currently available for many existing RNAV and FMS aircraft.

[1] Simplified Calculation assuming no wind, zero thrust and flaps 1 deceleration from 210 kt to 180 kt.
[2] Estimated noise level at airport surface level, under the flight path at WODY3.

Technical Approach: Intermediate CDA

Our technical approach gives the major planning functions for intermediate CDA to the ground ATC system, i.e. selection of path routing to merge sequential arrival traffic, and calculation of the CDA descent point would be primarily ground automation functions. The controller would communicate such information to pilots via 'Direct To' clearances and via CDA descent clearances, as the CDA aircraft approach the planned descent point. All aircraft (conventional and CDA) would be given conventional Final Approach course vectoring and speed clearances to transition onto final approach and to assure separation during the approach phase until glide-slope capture.

In order to support the planning function for integration of CDA and conventional aircraft traffic, we assume the development of an extended centerline 'Ghost Display' similar to that previously proposed by MITRE and the Dutch NLR [5] for integration of traffic arriving onto final approach from multiple routings. Figure 4 illustrates the Ghost Display concept for four aircraft arriving on two separate transition paths. Each aircraft that is in the process of transitioning to final approach is shown as both a 'real' aircraft on the display and as a 'ghost' on an extended final approach course. The ghost aircraft locations are chosen to match the arrival times of the real aircraft at the FAF, i.e. the ghost and the real aircraft converge to the same point as the aircraft transitions onto final approach.

The overall concept of operations is to enable 'feeder' controllers to plan the merging of CDA and conventional aircraft and to communicate such plans to pilots in the form of trajectory, altitude, and speed clearances. A subsequent 'approach' controller then provides final approach vectoring, speed clearances, and CDA descent clearances as needed to achieve desired separation on approach.