NOISE ABATEMENT APPROACH PROCEDURES

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Introduction

Operational noise abatement approach procedures have in recent years been subject of extensive research and development aimed at reducing community noise generated by arriving aircraft in airports vicinities. This paper describes results of an Airbus research project aimed at developing efficient noise abatement approach procedures. The project focused on Continuous Descent Approach (CDA) procedures that can be operated with in-service aircraft, either manually or in FMS managed mode. CDA procedures are defined as approach procedures without - or with minimum - recourse to level segments below a height of typically 7000ft. The project also considered benefits of more advanced approach procedures featuring optimised vertical profiles or increased glide slopes.

The paper starts with a description of the different procedures evaluated in the project and the project phases from inventory and parameter study to optimisation and flight simulator studies. Subsequently it reviews the main parameters driving approach noise and applied models. Thereafter results of the performance and acoustic studies and flight simulator evaluations are reviewed, including a review of operational issues that have been studied.

Main parameters affecting approach noise

The first phase of the design of approach procedures was limited to the definition of the vertical procedure. Turns in the arrival route and their impact on the noise signature on the ground are not considered in the definition of the vertical procedures. Atmospheric conditions are assumed to be standard for noise assessment. For a given aircraft and landing weight, the following operational parameters are considered as main parameters in the design of the noise abatement approach procedure:

- Height above ground level (AGL)
- Aerodynamic configuration: Flaps/slat angles, gear position, speed brakes deflection
- Airspeed
- Engine setting
- Descent angle

The aircraft height determines the source to observer distance and thereby the sound propagation losses due to spherical divergence and atmospheric attenuation. For positions lateral to the flight track, lateral attenuation of sound occurs for elevation angles (angle between sound ray and ground surface) lower than circa 30°.

The aerodynamic configuration and speed of the aircraft has significant impact on the airframe noise level. Figure 1 provides an example showing the strong influence of slat/flap deflection angles, gear position and airspeed on noise levels for an A340 for a constant approach power setting (Idle thrust). Table 1 provides slat/flap deflection angles for clean, intermediate and landing configurations.

CONF	Slats/flaps angles (°)	
	A320	A340
1	18/0	20/0
2	22/15	23/22
3	22/20	23/26
FULL	27/35	23/32

Table 1: Flaps/slats angles corresponding to A320 and A340 configurations.

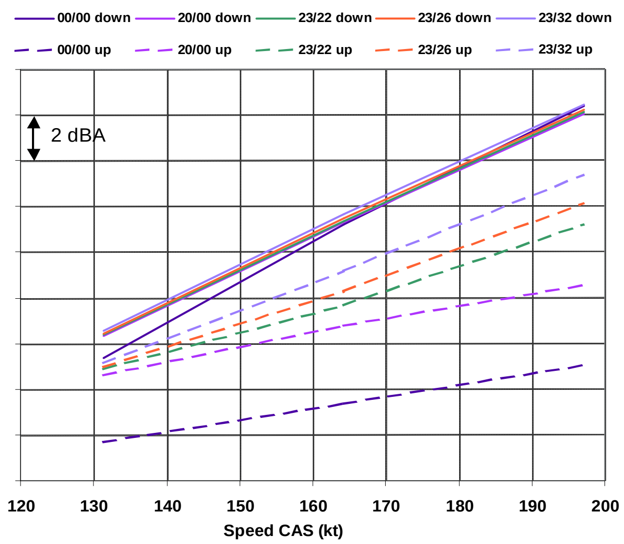

Figure 1: Influence of slats/flaps/gear configuration and speed on noise (Idle thrust)

Few data is available to quantify the impact of airbrakes on perceived noise. A340 flight-test noise measurements as part of a European research program have shown noticeable impact of relatively small spoiler deflections on overall airframe noise level, for an aircraft in intermediate/landing configuration. For the larger spoiler deflection angles that correspond to the 50% airbrakes setting, the relative impact is expected to be higher, especially when the aircraft is in clean configuration or in CONF 1.

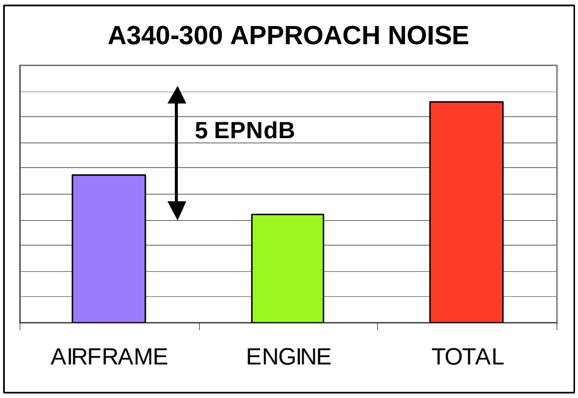

Figure 2: A340-300 airframe and engine noise components on approach.

In approach conditions, depending on aircraft type and configuration, the airframe noise can be as important as or greater than the engine noise. An example is given in Figure 2. For conventional approach operations, the engine thrust level varies along the approach trajectory between Idle thrust and the adapted thrust level required during constant speed level segments.

Fluctuations in thrust level, as a result of transients or adjustments to keep the aircraft on course in case of turbulence, can result in perceptible fluctuations of noise levels but have not been taken into account in the analysis.

The descent angle is a crucial parameter in the development of noise abatement approach procedures and has indirect impact on the noise exposure in three ways. The descent angle determines overall steepness of the profile and flyover heights along the profile. Secondly, the descent angle determines the amount of thrust required to maintain a given speed along a constant speed phase. An increase in descent angle leads to increased height profile and lower thrust, which both lead to less noise below track. A third aspect is the ability of the aircraft to decelerate along a descending path, which decreases with increasing descent angle. Decreased deceleration capability leads to longer deceleration segments and/or early deployment of slats/flaps or use of airbrakes. For the evaluated CDA procedures the speed profile and flaps/slats deployment schedule are partly determined by the descent angle.

Project and evaluated procedures

The project consisted of the following phases, described in this section:

1. Inventory and selection of procedures
2. Performance and noise parameter study and first optimisation
3. Procedure selection and flight simulator evaluations
4. Navigation, cockpit systems and handling qualities studies
5. Flight simulator evaluations and update of performance and acoustic studies

The procedures inventory was based on results of related research projects and on procedures tested or in operational use at airports. Preliminary results for a variety of CDA variants, featuring different flying techniques and height profiles, were available from the European Sourdine II project, in which Airbus participates [1]. The most basic CDA version featured a descent on a fixed 2° descent angle from CDA entry point to glide slope (G/S) capture. Other variants include steeper intermediate or final approach segments.

Experience and guidelines concerning the CDA procedure in operational use at London airports [2, 3, 4] were considered. The Code of Practice [3] provides guidance for airlines on the London CDA procedure. It identifies an optimum CDA descent angle of 3°. Investigating the capability of modern jet aircraft with high drag over lift ratios to simultaneously decelerate and descend using this angle (without systematic use of airbrakes) was as one of the tasks of this project. CDA procedures tested at Amsterdam, Louisville and Zurich airports [5, 6, 7, 8] were also considered.

Based on this inventory, a number of procedures were selected for analysis in the project upon noise criteria and operational applicability with the in-service fleet. This selection was accomplished through review meetings, involving engineers from aircraft performance, systems, handling qualities and acoustics departments as well as laboratory and flight test pilots. Operational aspects formed an important selection criterion. As an example, pilots were reluctant to procedures that involved a significant deceleration in an early stage. This eliminated some of the theoretic and airport procedures.

The second phase started with the definition of procedure variants for performance and noise studies. As baseline procedure an approach procedure similar to the FMS approach procedure was chosen. Figure 3 provides a schematic representation of the FMS-type baseline and a conventional approach profile. The baseline approach consists of three main segments. It starts at 7000ft AGL with a constant speed descent to glide-slope capture height, which is assumed to be 3000ft AGL. The second segment is a level deceleration segment until glide slope capture. The third segment is the final approach along the ILS glide slope. The aircraft stabilises in landing configuration and speed at or above 1000ft AGL. The landing speed and configuration correspond to maximum flap setting. The difference between the FMS and the conventional approach procedure is that in case of the FMS procedure the level segment length is based on the distance required to decelerate to CONF 2 speed. In operational practice, for the conventional approach this segment may consist of a downwind, turn and final leg and its length may vary as a function of airport, arrival route and of ATC sequencing instructions. Using the FMS approach as baseline enabled CDA comparison against best possible practice that can be achieved with the current aircraft fleet (from an aircraft point of view). The difference between this baseline and a conventional approach procedure has been quantified and is given in this paper.

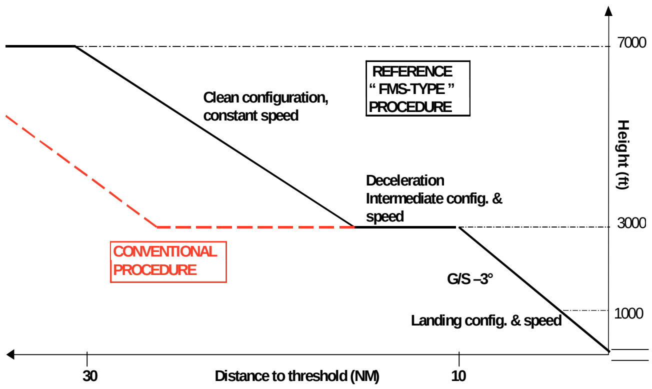

Figure 3: Conventional and baseline (FMS-type) procedures

Figure 4 shows the CDA profiles that were defined for the first performance and noise assessment. The procedures are initiated at 7000ft AGL, at 220ktCAS or Green Dot speed (standard speed for CONF 1 activation) whichever is highest. A parameter study involving CDA with flight path angles (FPA) varying from –2 to –3° was performed (blue profiles). Along the descent to 3000ft AGL the aircraft decelerates to intermediate flap speed, activating slats/flaps on schedule. After glide slope capture at 3000ft AGL the procedure is identical to the baseline. The goal was to define the maximum descent angle and associated noise exposure. Performance evaluations were made using 50% airbrakes to determine the extent to which airbrakes could contribute to enabling higher steeper profiles. Noise computations were not possible for these variants, but it was expected that airbrake deflection would increase airframe noise.

The parameter study preceded an optimization study, in which the energy management procedure was adapted, in order to obtain additional noise reduction. On an experimental basis, a CDA featuring a –2° intermediate descent combined with an increased final glide slope was included (CDA IGS, purple profile).

In the third phase, procedures were tested on an Airbus A340 flight simulator to evaluate in-flight characteristics and pilot perception.

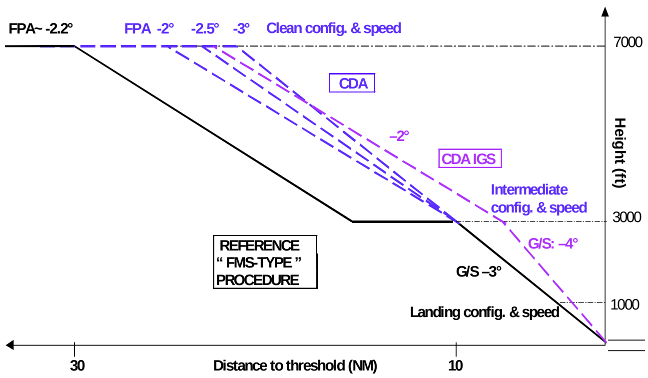

Figure 4: Baseline and CDA procedure variants

The tests, involving several test pilot crews, were performed for operational and maximum landing weights, under standard and adverse weather conditions.

Based on the outcome of the previous phases, the fourth phase comprised operational navigation and handling quality studies. The navigation and cockpit system studies were aimed at means to facilitate CDA operations using existing cockpit and navigation systems. Handling qualities and performance studies were undertaken to define speed constraints for optimised CDA procedures.

The final project phase consisted of a series of flight simulator test to evaluate the outcome of the navigation studies. It also included an update of the performance and noise analyses to update optimised procedures using the performance and handling qualities constraints.

Performance and noise models

The Airbus aircraft performance department computes approach trajectories for given procedures using the OCTOPER operational aircraft performance software. This tool enables calculation of operational departure and approach trajectories. It relies on aircraft type specific aerodynamic and engine specific thrust databases and integrates the aircraft in-flight equations of motion for all parts of operational approach (and takeoff/departure) procedures.

Using these operational approach trajectories as input, the noise analysis is performed using the Airbus Noise Level Calculation Program (NLCP). The NLCP was used in combination with adapted acoustic databases, including noise data for each individual approach slat/flap configuration, to enable accurate prediction of noise for operational approach procedures. Currently the NLCP does not model noise generated by deflected airbrakes.

The noise metrics used for the noise analysis are the maximum A-weighted noise level (DBAmax) and the A-weighted Sound Exposure Level (SEL). DBAmax noise levels are easier to correlate to aircraft performance along the trajectory than SEL and are considered as more representative for nighttime approach noise annoyance. DBAmax was therefore considered as main parameter.

Performance and noise studies

As a first step a comparison of noise impact for the chosen FMS baseline procedure and a conventional approach procedure is made. The conventional procedure was similar to the baseline, except for the level segment in which a constant speed segment was inserted, stretching the level segment to about 10NM.

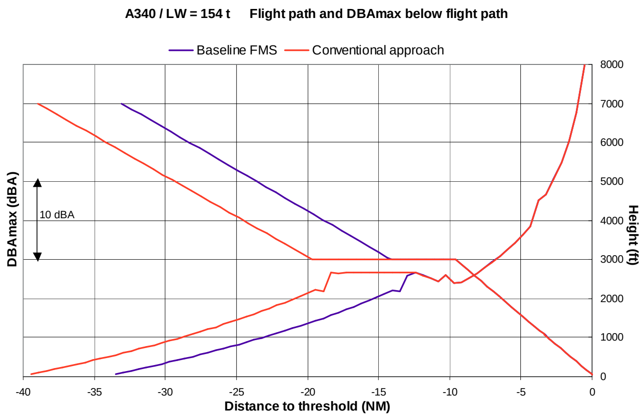

Figure 5: Vertical profile and noise for baseline and conventional procedure

Figure 5 shows that the conventional procedure is up to 5dBA noisier than the baseline procedure, for this aircraft type mainly due to the lower vertical profile.

Table 2 describes the procedures evaluated in the parameter study. Computations involved A320 and A340 aircraft and per aircraft several landing weights, including the maximum landing weight (MLW). Performance computations showed that the steepest common FPA, along which all aircraft/weight variants could decelerate without use of airbrakes, was -2°. For some weights variants -2.5° could be obtained. Using airbrakes enabled steeper angles up to -3°.

Analysis of the noise results for the –2° FPA CDA revealed a modest noise reduction for this CDA variant, compared to the baseline procedure. An example is given in Figure 6. Along the CDA slope the deceleration distance is longer than along a level segment, requiring earlier deployment of slats/flaps CONF 1 and 2 for the CDA, at respectively 22 and 12NM from threshold. The associated noise increase, distinguishable in the noise profile, eliminates noise reduction obtained with increased height during part of the CDA approach.

Procedure Altitude (ft)	CDA Intermediate descent FPA: -2, -2.5, -3
7000ft	- Initial point: Max (220kt CAS, V green dot), Flight Idle, Conf 0, Ldg Up - Descent
7000 - 3000 ft	- Descent Flight Path Angles (FPA): -2°, airbrakes 0 or 50% -2.5°, airbrakes 0 or 50% -3°, airbrakes 0 or 50% - Thrust Idle - Green dot speed → CONF1 - S-speed → CONF2
~ 3000 ft	- G/S intercept
Below 3000 ft	- if CONF2 → L/G down - F-speed → CONF3 - F-speed → CONF FULL - Decelerate to Vref+5
Upon reaching Vref+5, above 1000ft	- Descent at constant speed - Adapted thrust -3°G/S - Procedure end at 50ft AGL

Table 2: Procedures evaluated in parameter study

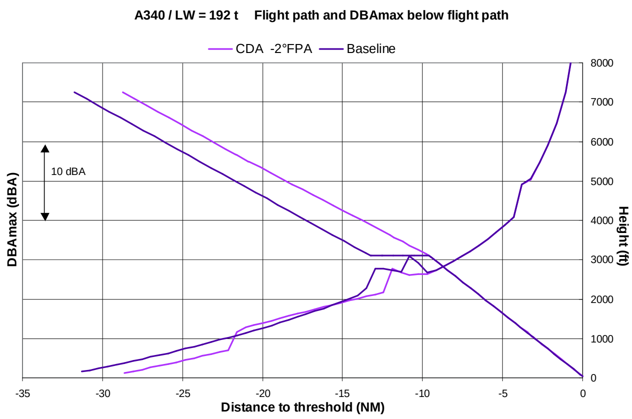

Figure 6: Height and noise profiles for the –2° FPA CDA and baseline FMS approach

The technique chosen to further reduce noise for the CDA procedure consisted in postponing the deployment of the slats and flaps and increasing the steepness of the procedure where possible. Postponing slats/flaps deployment was accomplished by activation of configurations CONF 1 and 2 at speeds below standard advised speeds and by using constant speed segments at the minimum slats/flaps change speeds. The constraint was to ensure stabilisation in landing configuration at 1000ft AGL. Increasing the profile steepness was possible during the constant speed segments. In addition, the landing gear was lowered upon CONF 3 instead of upon CONF 2 establishment. Between the advised speeds and minimum speeds for slats/flaps activation a margin exists with a size depending on aircraft, weight and flap setting. Minimum speeds are imposed either by performance or handling qualities limitations. A first optimisation was undertaken using speeds related to lower selectable speeds to evaluate the concept. The resulting noise reduction below track reached a maximum of 5dBA compared to the baseline.

A second optimisation round was based on a full and more stringent set of speed constraints identified by Airbus handling qualities and performance departments for single aisle and long range aircraft. An example of the resulting vertical and noise profile is given in Figure 7. For the optimised CDA profile the reduction of the speed at which CONF 1 and 2 are deployed and the optimised sequence of segments leads to postponed activation of both configurations and an increased height profile. The optimised CDA provides noise reduction underneath the entire CDA part until glide slope capture, with a maximum of 4dBA.

Further to the optimised version of the CDA procedure developed in this project, the noise impact of CDA procedures combined with increased glide slope has been quantified. The example in Figure 8 shows the noise profile for an A320 profile combining a –2° CDA segment with a –4° glide slope. Configuration and landing speeds are assumed the same for the baseline and increased glide slope and airbrakes are not used. The 1° glide slope increase provides up to 5dBA noise reduction underneath the final glide slope. Underneath the CDA approach, the noise reduction is up to 4dBA.

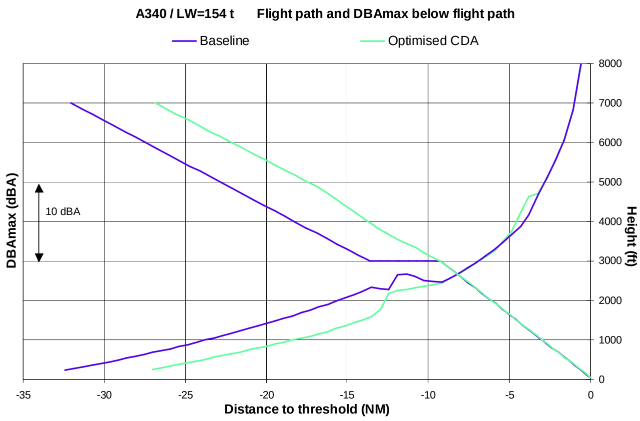

Figure 7: Height and noise profiles for the optimised CDA and baseline FMS approach

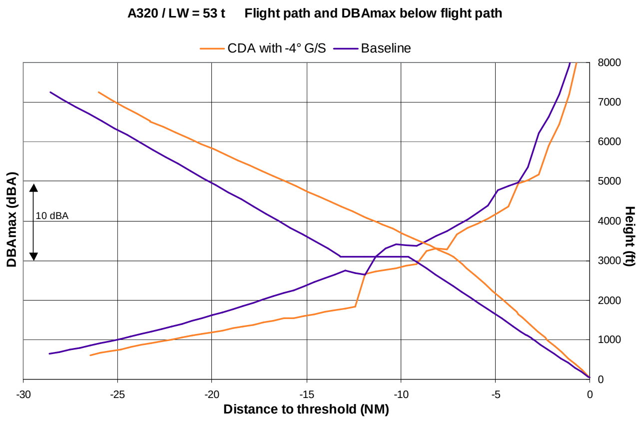

Figure 8: Height and noise profiles for a CDA with –4° glide slope and baseline FMS approach

Flight simulator and operational studies

The project included two series of flight simulator evaluations. The first series of evaluations were aimed at safety, operational feasibility and crew acceptance in terms of geographic profile definition and energy management.

The first series consisted of four sessions: two familiarisation sessions with laboratory pilots and two evaluation sessions with flight test pilots. They were carried out on A330 and A340 flight simulators. The scenarios were based on the London Heathrow horizontal arrival routes. Vertical procedures were as defined by the project. The arrival procedure was LAM3A with approach ILS27L, starting at 7000ft AGL.

The first tests with CDA procedures in manual mode were aimed at evaluating the vertical profiles defined for the parameter study. These tests confirmed that, without use of additional drag, the maximum flight path angle allowing deceleration for all evaluated weights was -2°. The pilots expressed need for guidance on the modified energy management procedure along the continuous descent.

Concerning the evaluation of the optimised procedures, pilots were reluctant to apply lower than advised flaps/slats activation speeds, considering that this was in conflict with standard operating practice.

Further evaluations were carried out using managed mode. The pilots expressed a clear preference for flight in managed mode, leading to less workload, inclusion of wind correction in flight management and indications on use of airbrakes to avoid excess energy.

The second series were aimed at evaluating the use of existing navigation systems to facilitate CDA operations. For these evaluations, carried out on the A320 simulator, known CDA profiles for a number of European airports were coded in the Navigation Database, to evaluate this type of guidance when used with CDA procedures. A small number of navigation/guidance functions were evaluated on their aptness to facilitate CDA operations for different levels of predictability of the horizontal routes. To allow efficient use of vertical navigation functions for facilitation of CDA operations knowledge of the horizontal trajectory is required.

Conclusions

CDA procedures have been analysed and optimised in terms of noise and performance. Airframe noise, a major contributor to overall approach noise for modern large commercial jet aircraft, was considered as main factor in the design of noise abatement approach procedures.

The FMS procedure used as baseline in the project appeared to be up to 5dBA less noisy below track than conventional approach procedures, due to its short level segment.

For the evaluated CDA procedures, performance and flight simulator studies showed that the steepest practicable CDA flight path angle without use of additional drag is about –2°. Non-optimised, this procedure provides modest noise reduction compared to the baseline. The optimised CDA and the increased glide slope procedures provide significantly more noise reduction of up to 5dBA compared to the baseline.

Flight simulator sessions have demonstrated a pilot preference for managed mode over manual operations. Further requirements are clear guidance on energy management and, to facilitate vertical navigation using existing systems, knowledge of the horizontal track.

References

1. Sourdine II, “D5.3 Single event noise calculations”, Sourdine II public document, June 2003.
2. ANMAC Technical Working Group, “Noise from arriving aircraft”, UK Department of the Environment, Transport and the Regions, December 1999.
3. Anon., “Noise from arriving aircraft, an industry code of practice”, UK, September 2001.
4. Elmer, K. et al, “A Study of Noise Abatement Procedures using Ames B747-400 Flight Simulator”, Paper AIAA 2002-2540, 2002.
5. Anon., Jeppesen chart Amsterdam CDA ILS DME Rwy 06, 18 JAN 02, Jeppesen Sanderson, Inc., 2002.
6. Warren, A. and K. Thong, “Development of Continuous Descent Approach Concepts for Noise Abatement”, Boeing ATM paper 21st DASC, 2002.
7. Hänny, J., Skyguide Experience LSZH CDA RWT 14/16, Skyguide presentation AOT12, February 2003.
8. Bänninger H., “Continuous Descent Approach”, IATA presentation AOT12, February 2003.