Environmental Research and Consultancy Department

Review of Arrival Noise Controls

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Chapter 1

Introduction

Whilst departure noise limits have been in place as long ago as 1959 in the case of Heathrow airport, no formal limits or penalties have applied to arrival noise at the designated airports. It has been long-standing Government policy that controls and penalties to manage arrivals noise could incentivise unsafe behaviour. The rationale for this is that an arrival is generally a more safety critical period of flight than a departure and that, especially in the busy London Terminal Control Area, pilot workload is high during the approach phase of flight.

Going as far back as the 1970s, CAA studies[1] have instead focused on encouraging best practice measures to reduce arrival noise in the form of Continuous Descent Operations (CDO), which aim at keeping aircraft flying higher for longer during their approach, and Low Power/Low Drag (LP/LD) procedures, maintaining a 'cleaner' aircraft configuration for longer. A CDO is commonly referred to as a Continuous Descent Approach (CDA) in the UK, which typically starts from an altitude of 6,000 feet. However, the term CDO is used throughout this report in keeping with international usage.

During the 1990s the Government considered the feasibility of setting noise limits for arriving aircraft through its Aircraft Noise Monitoring Advisory Committee (ANMAC[2]). ANMAC advises the Department for Transport on technical and policy aspects of aircraft noise mitigation and track-keeping policies at Heathrow, Gatwick and Stansted airports. Its membership includes representatives of Heathrow, Gatwick and Stansted, those airports' consultative committees, the three airport scheduling committees, the CAA, NATS and the Department for Environment, Food and Rural Affairs (Defra).

The work was published by the Department of the Environment, Transport and the Regions (DETR) in 1999, which concluded that it was impracticable to set approach noise limits similar to those for departing aircraft[3]. Instead, the ANMAC report set out a range of options to reduce noise including a new code of practice to promote the use of CDOs and closer industry co-operation. *Noise from Arriving Aircraft; An Industry Code of Practice* was subsequently published in 2002 and later updated in 2006[4]. After the publication of the

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[1] The Noise Benefits Associated With Use of Continuous Descent Approach and Low Power/Low Drag Approach Procedures at Heathrow Airport, CAA Paper 78006, Civil Aviation Authority, April 1978

[2] ANMAC is currently known as the Aircraft Noise Management Advisory Committee, the name changing from Aircraft Noise Monitoring Advisory Committee in 2010/11.

[3] Noise from Arriving Aircraft: Final Report of the ANMAC technical working group, Department of the Environment, Transport and the Regions (DETR), December 1999

[4] Noise from Arriving Aircraft: An Industry Code of Practice, 2nd Edition, Department for Transport (DfT) et al., November 2006

DETR report, the requirement to fly a continuous descent arrival was incorporated into the designated London airports' Noise Abatement Procedures[5].

The voluntary Code was compiled and produced by a group representing airlines, air traffic control (NATS), airports, the CAA and the Department for Transport. Whilst the Code recognises the benefits of LP/LD approach procedures as a means of reducing noise, the key factor identified is the noise benefit that can be obtained from greater achievement of CDOs, the objective being to ensure aircraft remain as high as possible for as long as possible. In addition to reducing noise, CDOs and LP/LD procedures also reduce fuel burn and emissions, thereby producing an overall environmental benefit.

The code of practice has contributed to enhanced arrivals noise mitigation, and in particular CDO, in the UK and also worldwide. However, recognising that noise disturbance is still a key concern for many residents living under the approach routes to airports, the Government announced in its March 2013 Aviation Policy Framework that ANMAC would review the departure and arrivals noise abatement procedures, including noise limits and use of penalties, to ensure that these remain appropriately balanced and effective. This report summarises the work completed in respect of approach noise.

Much of the work in support of this review was carried out by the CAA's Environmental Research and Consultancy Department (ERCD) in close collaboration with other members of the ANMAC Technical Working Group (TWG), whose membership is listed below.

TWG membership	
CAA ERCD (Chair and Secretariat)	Heathrow Scheduling Committee
Department for Transport	Technical Adviser to the Scheduling Committees
Heathrow Airport	Gatwick Airport Consultative Committee (GATCOM)
Gatwick Airport	Stansted Airport Consultative Committee (STACC)
Stansted Airport	NATS

The TWG's terms of reference were:

- Identify, as far as practically possible, the principal reasons for failing to achieve a CDO at the designated airports. Review and assess the difficulties that are likely to occur in applying penalties for not achieving a CDO.
- Review and assess the extent to which LP/LD techniques are applied at the designated airports, whilst having due regard to safety, capacity and other constraints.

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[5] EGLL AD 2.21, EGKK AD 2.21 and EGSS AD 2.21, UK Aeronautical Information Publication (AIP).

- Review and assess the difficulties in monitoring arrival noise, especially prior to glide path intercept. Review to what extent noise monitoring can and cannot be used to identify non-CDO and/or non-LP/LD approaches.

Chapter 2 summarises the operational factors that can affect noise from arriving aircraft. Chapter 3 provides an overview, for information purposes, of other factors affecting approach noise that were outside the TWG’s terms of reference. Chapter 4 reviews the factors in monitoring arrivals noise and the extent to which noise monitoring can be used to identify non-CDO and/or non-LP/LD approaches. Chapter 5 presents the conclusions of the study.

Chapter 2

Operational factors affecting approach noise

Background

Modern aircraft generate significantly less noise on departure and arrival than their predecessors as a result of technological innovation and the use of noise abatement operating procedures. The impact of approach noise has become relatively more important due to the following factors:

- The heights of aircraft on final approach are determined by the Instrument Landing System[6] (ILS), which involves aircraft flying at lower altitudes compared to departures at equivalent distances from the airport, albeit requiring lower levels of thrust.
- The increasing size of aircraft with the increased airframe noise that this can generate, which can be a significant component of the total approach noise when engine power is low.
- The increase in the number of movements at airports.

As mentioned in Chapter 1, the 1999 ANMAC arrivals report concluded that it was impracticable to set approach noise limits similar to those for departing aircraft. Government therefore decided against imposing operational noise limits for arrivals and in February 2000 announced that it would ask the aviation industry to develop a code of practice to promote the use of CDO, which the report had identified as the primary means of reducing noise experienced on the ground.

Following initial publication of the code in 2002, the designated airports commenced regular monitoring and reporting of CDO performance through the use of their Noise and Track Keeping systems (NTK), along with an engagement programme with airline operators and NATS to promote CDOs and outline the benefits in terms of noise and fuel burn. As a result, CDO performance has improved significantly across the three London airports since the introduction of the Code. At Heathrow for example, daytime CDO compliance in 2015 was 87 percent, compared to 76 percent in 2001. CDO procedures are now widely used at airports throughout the world.

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[6] A ground-based system that provides lateral (the localiser) and vertical (the glide path) guidance to an aircraft approaching and landing on a runway.

Continuous Descent Operation

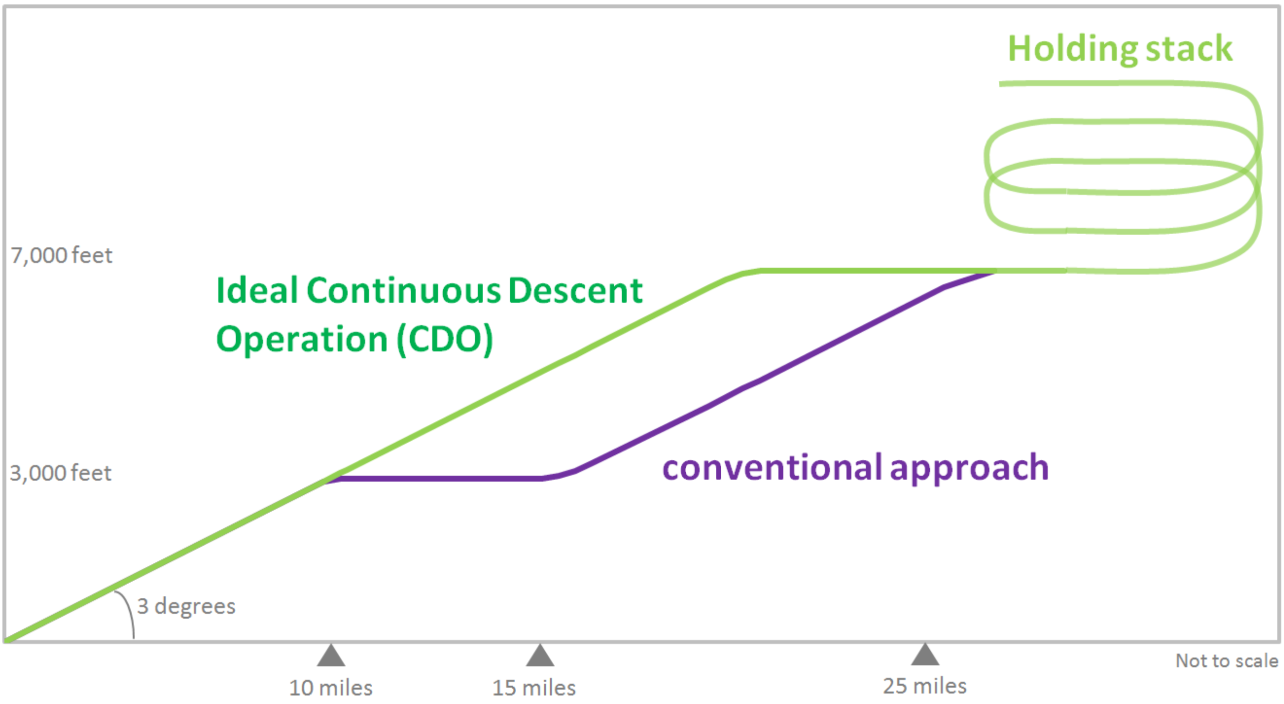
The arrivals code of practice defines an arrival as a CDO if it contains, below an altitude of 6,000 feet:

- no level flight; or
- one phase of level flight not longer than 2.5 nautical miles (NM)

In order to set aircraft up for approach to landing, Air Traffic Control (ATC) descend aircraft and reduce their speed. During busy periods, arriving aircraft can be directed by ATC to holding stacks. A holding stack is a fixed circling pattern in which aircraft fly whilst they wait to land.

With a conventional (non-CDO) aircraft approach, an aircraft would be given clearance by ATC from the bottom level of the holding stack (normally a Flight Level equivalent to 7,000 feet) to descend to an altitude of typically 3,000 feet. The aircraft would then be required to fly level for several miles before intersecting the 3 degree glide path to the runway. During this period of level flight, additional engine power would be required to maintain level flight at a constant speed (**Figure 1**).

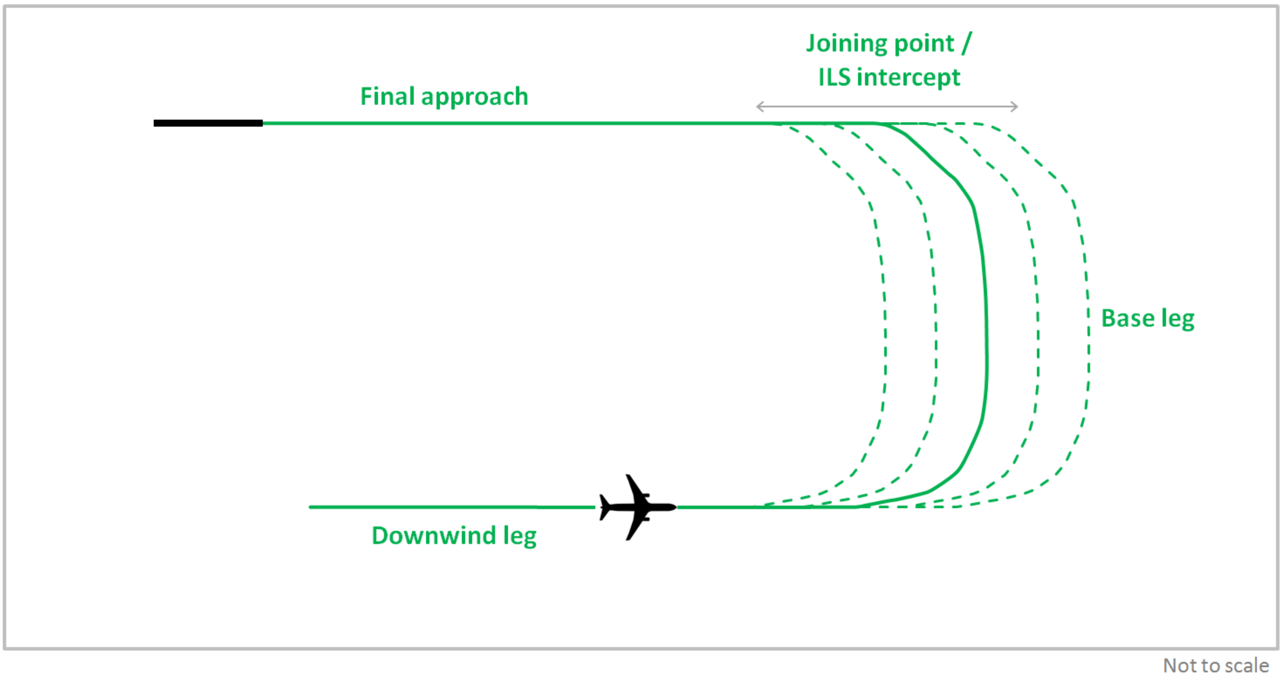
Figure 1 Comparison between a CDO and a conventional approach



In contrast to a conventional approach, when a CDO procedure is flown the aircraft stays higher for longer, descending continuously from the level of the bottom of the stack (or higher if possible) and avoiding any extended level segments of flight prior to intercepting the 3 degree glide path. A continuous descent also requires significantly less engine thrust than required for level flight. CDO descent rates vary, such that an optimal CDO will require idle power from the engines, whereas in some cases CDO is achieved by applying a reduced rate of descent, requiring thrust above idle. This applies even for an aircraft in turning flight.

Because, generally in the UK, there are no mandatory flight paths between the holds and joining the final approach it is the responsibility of ATC to instruct pilots to fly specific headings at appropriate times. This is a process known as vectoring, which occurs prior to aircraft being directed into the arrival sequence and intercepting the ILS, and means the track distance covered during the approach will vary from flight to flight (**Figure 2**). To enable pilots to manage their descent, a CDO procedure therefore requires ATC to pass on accurate 'range from touchdown' information to the air crew.

Figure 2 Illustrative ILS approach procedure



The downwind and base leg portions of the approach path can be more complex than those indicated in **Figure 2**, sometimes appearing as an 'S' shape. The point at which aircraft intercept the ILS is known as the joining point and whilst the precise joining location can vary significantly from flight-to-flight depending on operational conditions, each airport generally has its own minimum height and distance requirements (which can also vary depending on the time of day). A study of arrival joining point and its effect on flight path concentration was outside the scope of the TWG review. However, recent evidence is available that shows how the average joining points at Heathrow and Gatwick have varied over time due to a variety of operational reasons[7,8].

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[7] Gatwick Airport Independent Arrivals Review, Report and Recommendations, Bo Redeborn and Graham Lake, Jan. 2016. http://www.gatwickairport.com/business-community/aircraft-noise-airspace/airspace/arrivals-review/ (accessed 19 June 2017).

[8] LHR Joining Point Distance Analysis for 2015, Heathrow Airport Limited, May 2016. http://www.heathrow.com/noise/facts,-stats-and-reports/reports (accessed 19 June 2017).

It is sometimes not possible to achieve a CDO due to a range of factors, including ATC instructions and information, airspace constraints, overriding safety requirements and weather. An analysis of CDO achievement rates over a period of several years may show seasonal peaks and troughs in performance. Non-achievement has been shown to be due to extended vectoring below the monitoring height threshold for a variety of reasons. Variations in performance can also be affected by runway direction due to interaction of departing traffic and air traffic from other airports. In addition, when flying a CDO an aircraft may still require a short segment of level flight in order to reduce speed and/or to reconfigure. Thus without knowledge of the associated ATC voice instructions to flight crew (the monitoring of which would be impracticable), any instances of non-CDO could not automatically be attributed to the flight crew, making it difficult to apply financial or other penalties for not achieving a CDO.

The noise benefit of a CDO will vary depending on the altitude and length of level flight associated with a non-CDO, as well as the descent rate and associated thrust settings of the CDO flight. Previous analysis has shown that a typical non-CDO has approximately 5 NM of level flight at altitudes from 3,000 to 6,000 feet. Compared to a perfect CDO, this results in noise increases of up to 2.5 to 5 dB, varying over distances from touchdown of 10 to 20 NM (**Figure 3**).

Since the minimum Flight Level of aircraft in the holding stacks around the London airports is equivalent to 7,000 feet, for practical reasons the arrivals code of practice considered the noise benefits of CDOs below 6,000 feet[9]. One outcome from Gatwick Airport's recent Independent Arrivals Review was for the minimum altitude for the commencement of CDO to be increased to 7,000 feet, with a further increase to 8,000 feet when feasible. Gatwick is currently working with NATS to take the necessary measures to raise the commencement of CDO from 6,000 feet[10], although it is unclear at this time whether such changes will result in any measureable noise reduction on the ground. At UK airports outside of the London area, NATS has been working alongside Sustainable Aviation to improve CDO performance from higher altitudes (up to 25,000 feet) in order to save fuel and reduce CO_2 emissions as well as to reduce noise[11].

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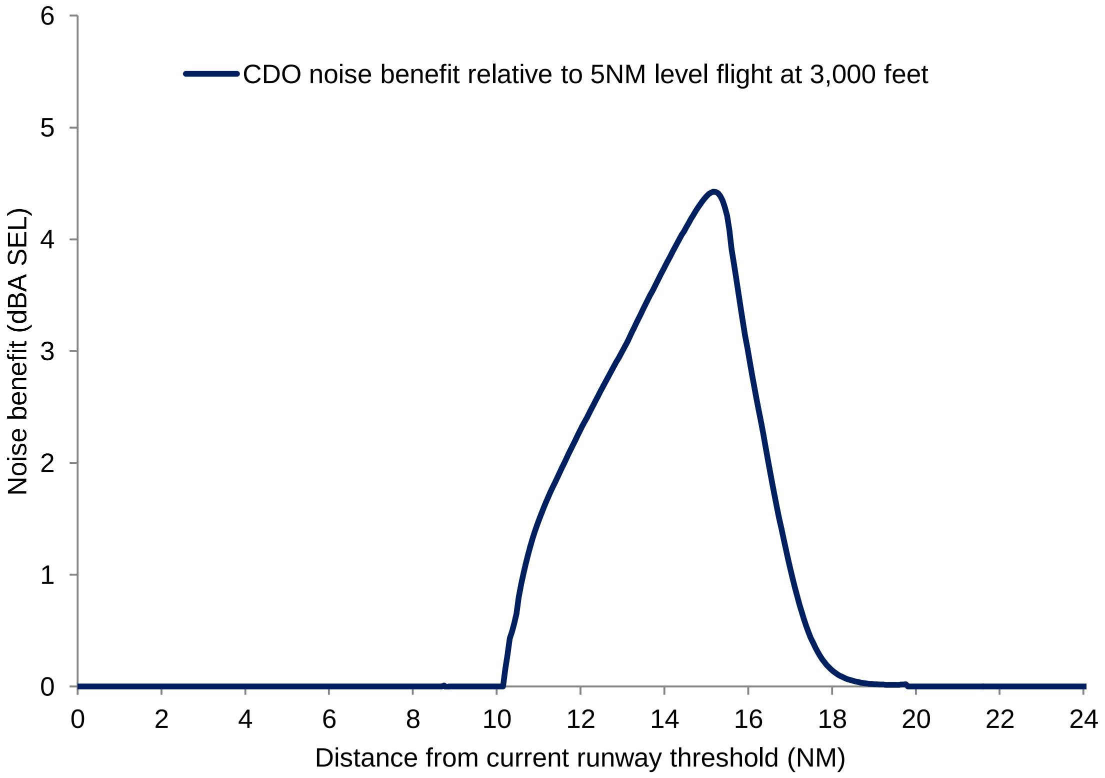
[9] The code of practice recognised that, given the constraints of the airspace in the London area, the highest practicable level a CDO can commence for Heathrow, Gatwick and Stansted was 6,000 feet.

[10] Gatwick Arrivals Review, Overview and Final Action Plan, Gatwick Airport Limited, June 2016. http://www.gatwickairport.com/business-community/aircraft-noise-airspace/airspace/arrivals-review/ (accessed 19 June 2017).

[11] Cleaner, Quieter and Smarter! Continuous Descent campaign delivers tangible improvements, NATS, 18 August 2015. http://nats.aero/blog/2015/08/cleaner-quieter-and-smarter-continuous-descent-campaign-delivers-tangible-improvements/ (accessed 19 June 2017).

Figure 3 Noise benefit of Continuous Descent Operation for one aircraft type (Boeing 777)



Low power/low drag

For the vast majority of arrivals, aircraft speeds are controlled by ATC instructing pilots to fly at set speeds. As an aircraft reduces speed during the intermediate approach phase (after leaving the holding stack) to comply with ATC instructions, flaps are deployed to allow the aircraft to fly slower and prepare the aircraft for landing. For a given aircraft type and mass, each flap setting has a minimum safe flight speed. Landing gear is typically deployed in the final approach phase in accordance with safety criteria, and for some aircraft its deployment can also be linked to a flap setting.

Low power/low drag is the collective term used for describing the lowest noise configuration for a given speed and/or altitude during the approach. Selecting more flap than is required for a given speed will typically lead to more airframe noise, higher engine power due to greater drag and thus higher noise. The effect is however small, typically no more than 1 dB.

In contrast deployment of the landing gear significantly increases aircraft drag and airframe noise, and to maintain the flight path requires increases in engine power and thus also engine noise. The combined effect may be as much as 5 dB.

Landing gear are deployed in accordance with airline and manufacturer safety requirements and standard procedures, which vary by aircraft type. This translates into landing gear deployment not normally being later than 5 NM/1,500 feet above airfield level, in order to prevent late deployment. This is to ensure a safe stabilised approach in the landing configuration is achieved by 1,000 feet – if this doesn't happen, a go-around must be carried out for safety reasons.

Monitoring of the use of LP/LD procedures would necessitate knowledge of the position of flaps and undercarriage during the entire approach. Whilst it is relatively straightforward to visually monitor the position of the undercarriage, determining the precise position of the flaps is only possible through analysis of onboard flight data[12] (e.g. Quick Access Recorder), which may only be available for selected airlines and in small quantities.

The previous work[3] highlighted limited noise benefit could be obtained from optimising flaps but did not study landing gear deployment in great detail. However, more recent CAA analysis of landing gear deployment conducted in 2013 and 2014 is presented in Appendix B which indicated that approximately 12 percent of arrivals at Heathrow deployed their landing gear before reaching 8 NM from threshold. A relatively large proportion of these aircraft were operated by Middle-Eastern and Asian carriers. A subsequent study carried out by Heathrow in 2015 also demonstrated significant variation of deployment procedures amongst airlines operating the same aircraft type. Since then the airport has been working with airlines to optimise gear deployment and improve consistency[13].

Equivalent CAA analysis at Gatwick, where UK and European carriers accounted for a significant majority of monitored arrivals, showed that 7 percent of arrivals deployed their landing gear before reaching 8 NM from threshold. A similar study was not conducted at Stansted due to the lower overall number of daily movements and more limited mix of carriers compared to the other two airports.

Noise measurements from the study indicated that early landing gear deployment can increase noise by 3 to 5 dB (e.g. see **Figure 4**). Such an increase can be greater than the difference in noise between the latest generation of aircraft and the generation they replaced, over this part of the approach.

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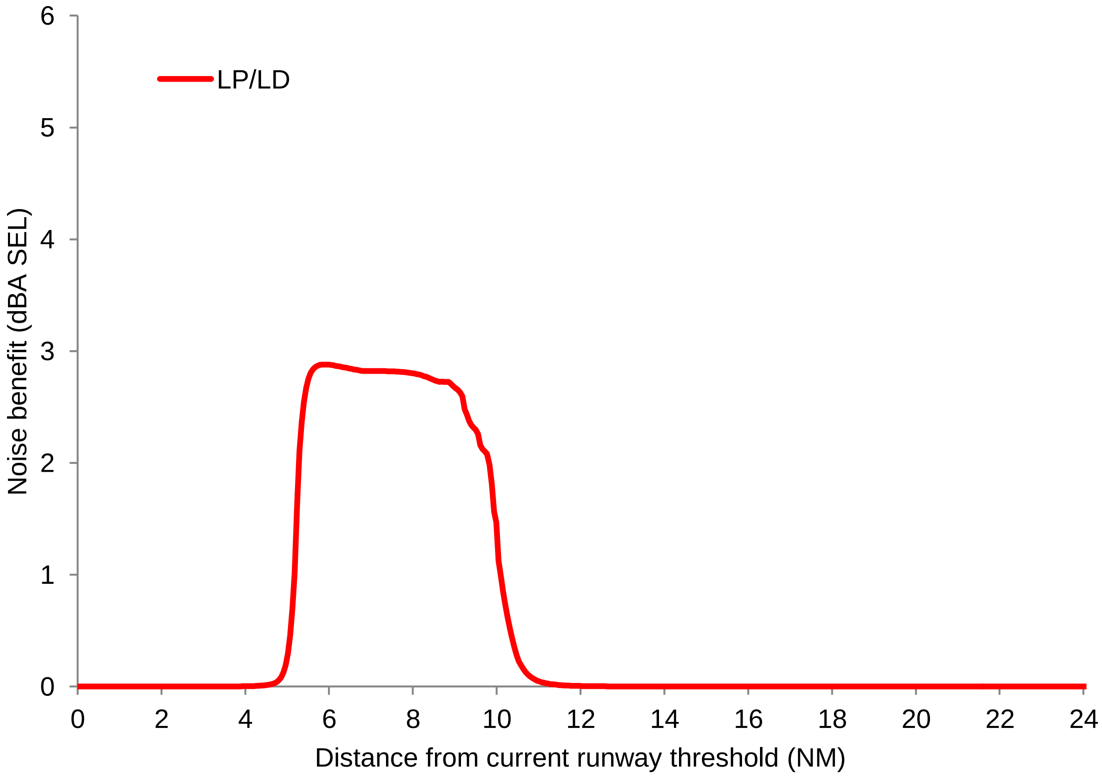
[12] See Annex 6 of *Noise from Arriving Aircraft: Final Report of the ANMAC technical working group*, Department of the Environment, Transport and the Regions (DETR), December 1999.

[13] Heathrow's Blueprint for noise reduction, Heathrow Airport Limited, August 2016. http://www.heathrow.com/noise/making-heathrow-quieter/our-noise-strategy/blueprint-for-noise-reduction (accessed 19 June 2017)

Figure 4 Noise benefit of good-practice landing gear deployment for one aircraft type (Boeing 777)



Reduced landing flap

Most aircraft are certificated with two or more landing flap settings. The full landing setting, which sets the flaps at their maximum angle, also produces their maximum drag and allows the aircraft to fly at the slowest speed, reducing runway occupancy time and less reliance on reverse thrust. Reduced landing flap settings set the flap angle to less than their maximum, resulting in lower drag and thereby requiring less engine power during the approach and resulting in less noise being emitted.

Reduced landing flap requires the approach to be flown at higher speeds, and therefore increases the touchdown speed, which can lead to increased brake wear, increased use of reverse thrust and increased or decreased runway occupancy time (depending on the location of runway rapid exit taxiways). However, it also reduces fuel burn and engine emissions and reduces stress on the flap system leading to maintenance savings for some aircraft. As a consequence, reduced landing flap is a widely adopted technique by many operators, where it is safe to do so, and some airports recommend this in their noise abatement procedures[14].

Reduced landing flap can result in noise reductions of 0.5 to 1.5 dB (see **Figure 5**), the larger figure typically being associated with older aircraft types. Since the landing flap is

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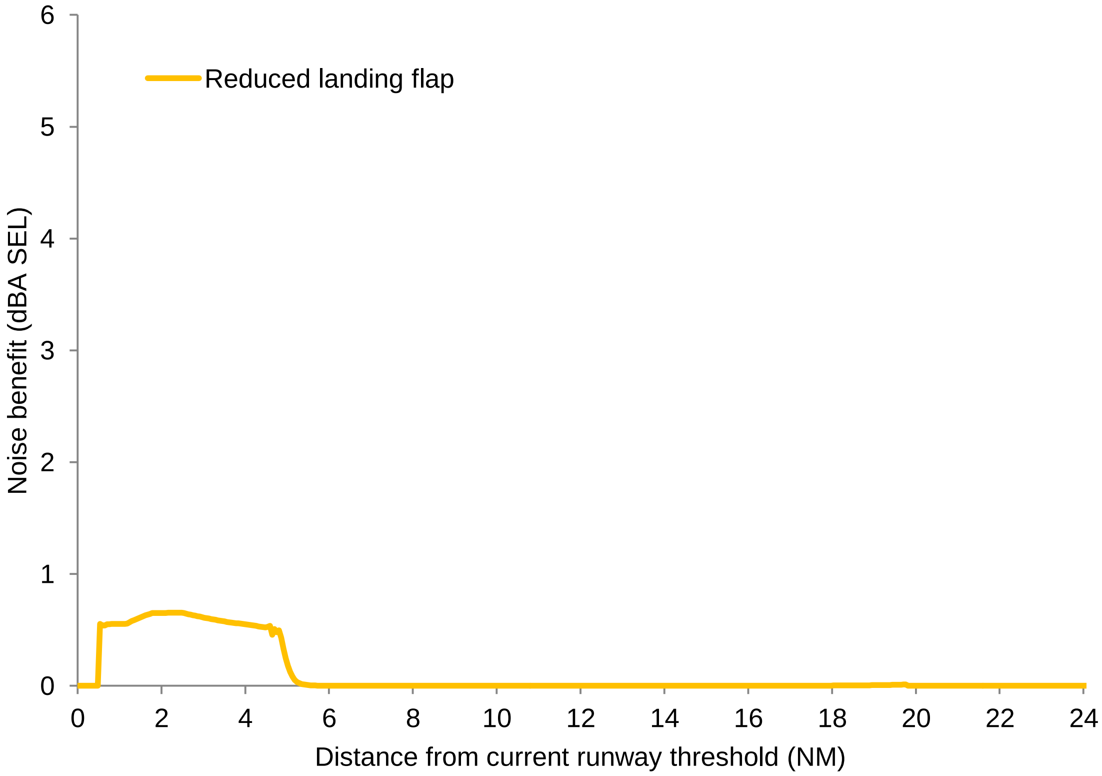
[14] AIP Japan, RJAA (Tokyo Narita) AD 2.21 Noise Abatement Procedures.

adopted just after the landing gear is deployed, it is typically selected at heights of 1,200 to 1,500 feet, i.e. 4 to 5 NM from touchdown. As such reduced landing flap reduces noise very close to landing. Although some operators already use this technique, uptake across UK airports is currently unknown.

Figure 5 Noise benefit of reduced landing flap for one aircraft type (Boeing 777)



Summary of operational factors

Whilst the operational arrival noise mitigation measures discussed above are already implemented to varying degrees at UK airports, they may be considered complimentary in that they provide noise benefits at different distances from landing and can be utilised as part of a coherent operational policy, as summarised below and illustrated in **Figure 6** and in cumulative form in **Figure 7**.

Distance from runway threshold	Procedure / technique
0 to 5 nautical miles	Reduced landing flap
5 to 10 nautical miles	Low Power/Low Drag (LP/LD)
10 to 20 nautical miles	Continuous Descent Operation (CDO)

Figure 6 Comparison of the benefit of individual arrival noise measures for one aircraft type (Boeing 777)

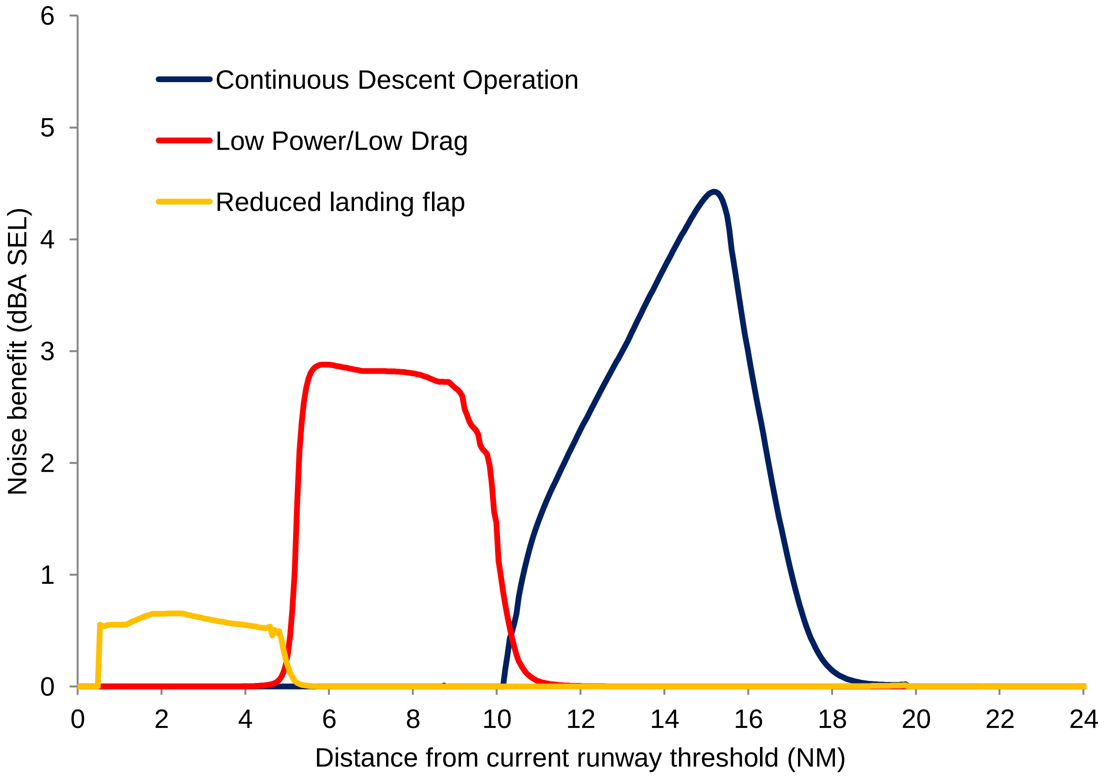
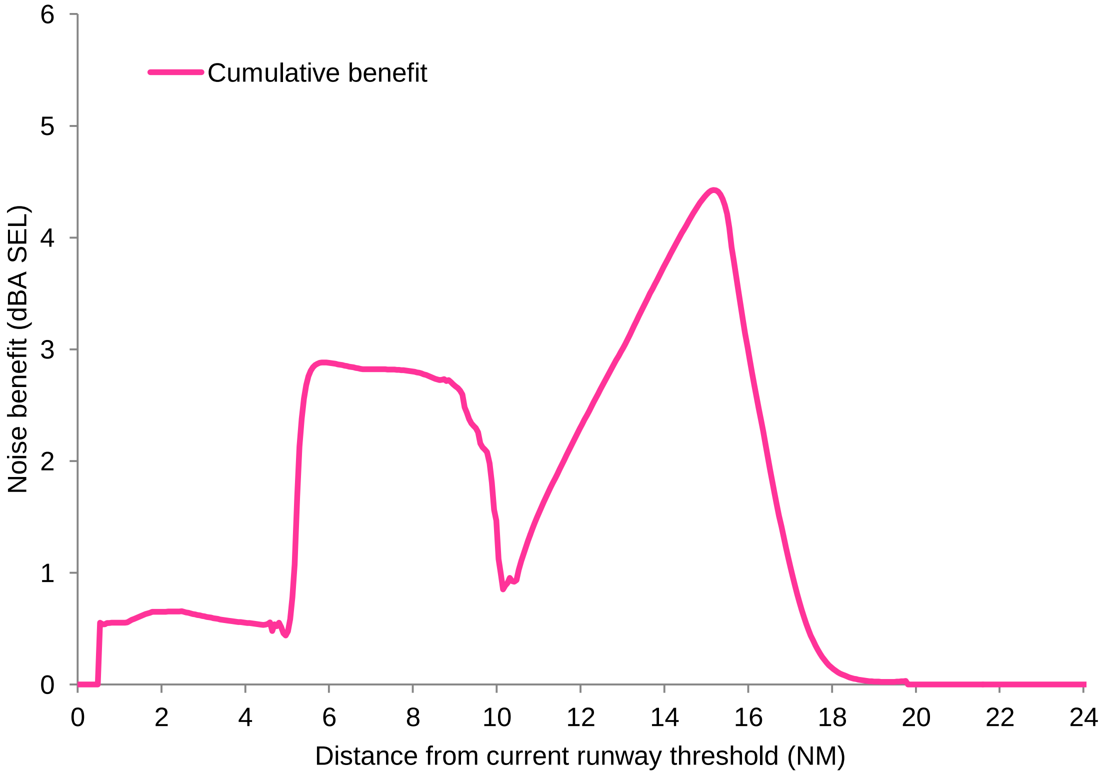


Figure 7 Cumulative arrival noise benefit for one aircraft type (Boeing 777)



Chapter 3

Other factors affecting approach noise

Steeper approaches

The international standard Instrument Landing System (ILS) glide path angle is 3 degrees. Increasing an aircraft's glide path reduces noise in two ways. Firstly, it slightly increases the height of the aircraft over the ground, increasing the distance over which sound travels before it reaches a population. Secondly, it increases an aircraft's rate of descent, and where engine power for a 3 degree descent is not at the minimum setting (idle), it will reduce the amount of engine power required and in turn reduce the amount of noise emitted.

Some airports in the UK already utilise glide path angles greater than 3 degrees to account for obstacles preventing the standard 3 degree flight path being adopted. The ability to land in low visibility conditions depends on the type of ILS system installed. ILS and associated onboard aircraft systems that provide the highest capability to land in poor visibility (CAT III) are generally limited to angles of 3.25 degrees, although some aircraft types are constrained to only 3.15 degrees approaches.

For most airports, the ability to continue operations in low-visibility condition is a key requirement that would dissuade it from adopting approach angles of greater than 3.25 degrees. In addition, ICAO[15] currently urges States not to adopt flight path angles greater than 3 degrees for environmental reasons.

Frankfurt airport's new runway, 07L-25R is required to have two ILS to enhance operational resilience. Since the existing ILS was already CAT III, the airport in addition installed a CAT I system at 3.2 degrees. Both systems operate simultaneously. In low-visibility operations, the CAT III 3 degree system is used, however, when conditions are appropriate, aircraft are directed to use the 3.2 degree system.

Steeper approaches (above 3 degrees) have been researched for a number of decades. Apart from a relatively small number of instances where a steeper approach is required for obstacle purposes they have not been adopted. More recently there has been renewed interest in approach angles just above 3 degrees for environmental purposes, i.e. where there is no obstacle requirement to be met. To distinguish between the two concepts, an approach with a glide path angle of between 3 and 3.25 degrees has become known as a *slightly steeper* approach.

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[15] ICAO Doc. 8168 (PANS-OPS) Volume I states that glide path or approach angles should not require an approach to be made above an angle of 3 degrees except where it has been necessary for operational purposes.

Heathrow airport trialled an RNAV 3.2 degree approach procedure between September 2015 and March 2016[16]. Although the trial was successful and was found to have no adverse impact on daily operations, unlike ILS approaches the RNAV procedure is sensitive to temperature and operating the trial during winter reduced the approach angle actually flown, from 3.2 to 3.14 degrees. Because temperatures above 15 degrees C will lead to angles above 3.2 degrees, the CAA requested further trials to be completed. As a result, the airport commenced a further 3.2 degree trial on 25 May 2017 to assess the effect of warmer temperatures on the approach angle flown during the summer months[17]. The end of the trial is currently planned for 11 October 2017.

An alternative concept to a slightly steeper approach is a two-segment approach. A two-segment approach adopts an intermediate approach phase flown at a steeper angle, before transitioning back to a standard 3 degree approach. This would potentially provide noise benefits further out during the approach, without affecting the final approach phase.

In 2014 British Airways provided flight simulator access and worked with the CAA to address and consider issues associated with the concept, including:

- Technical feasibility – can such a procedure be flown safely by all types?
- Environmental benefits – what is the magnitude of the benefits achievable whilst ensuring operations remain safe?
- Airport capacity impact – what impact might it have on airport capacity?
- Scalability – could it be deployed only at certain times of day and what might the training and oversight requirements be?

This work culminated in a series of proof of concept flights using Boeing 777 aircraft at Heathrow airport in late 2014 and early 2015. Flight crews reported that workload associated with the procedure was not dissimilar to standard approaches. ATC feedback was positive, although it was noted that the procedure could be challenging to implement in periods of high flow rate (due to the increased wake turbulence separation required for an aircraft following on a standard 3 degree approach), leading to the concern that airport capacity could be significantly affected, and further study would be required to understand the nature of that impact. A number of issues were raised which concluded not all aircraft were able to safely complete two-segment approaches.

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[16] 3.2° Slightly Steeper Approach Trial Report Aug 2016. Heathrow Airport Limited, August 2016. http://www.heathrow.com/file_source/HeathrowNoise/Static/Heathrow_Slightly_Steeper_Approach_Trial_Report.pdf (accessed 19 June 2017)

[17] http://www.heathrow.com/noise/latest-news/slightly-steeper-approach-trial (accessed 19 June 2017)

Displaced landing thresholds

Another practical method of mitigating the impact of aircraft noise is the displacement of airport runway thresholds from the extremity of the runway surface end to a location further down the runway. Displacing runway thresholds allow aircraft to fly at higher altitudes as they pass over communities located near the airport, thereby increasing the distance between aircraft producing noise and thus lowering noise on the ground. Runway thresholds have been displaced for many years to increase the clearance between approaching aircraft and obstacles located near the airport.

The International Civil Aviation Organization (ICAO) prescribes the following criteria:

“The practice of using a displaced runway threshold as a noise abatement measure shall not be employed unless aircraft noise is significantly reduced by such use and the runway length remaining is safe and sufficient for all operational requirements.” (ICAO Doc 8168, Part I, Section 7, Chapter 3, Page 4, Subsection 3.6).

Because assessments against the ICAO criteria are very site-specific, evaluation should be done on a case-by-case basis, and any airport considering the use of displaced runway thresholds as a noise abatement procedure would need to conduct a similar analysis under the ICAO criteria, but such analysis must be based on the specific conditions associated with that airport. A displaced threshold whilst providing noise benefits could have potential impacts on capacity, runway and airport infrastructure, operational resilience, air quality and of course its cost effectiveness would need to be considered against alternative measures, for example, displacing the landing point and the subsequent ground roll. Unless suitable exit taxiways already exist or are created, the ground roll may be extended affecting runway occupancy time and capacity. Alternatively, if greater braking and/or reverse thrust is used for existing exit taxiways, this may lead to additional air quality emissions, albeit displaced away from the airport boundary, and might also lead to increased ground noise.

Airframe noise

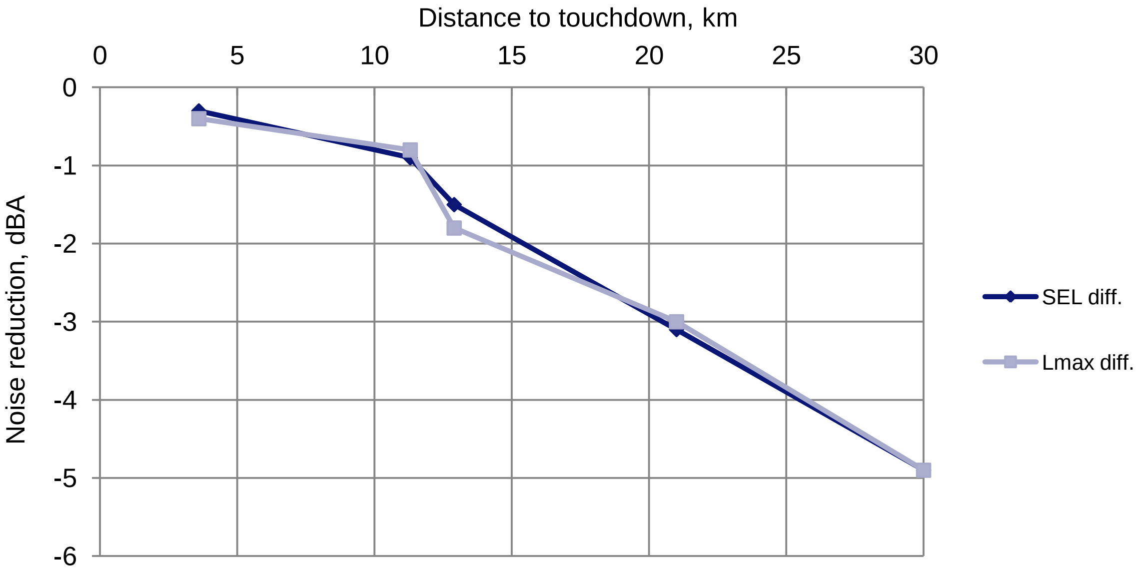
In addition to engine noise, the airframe itself, including components such as flaps and landing gear, can generate significant noise during approach, which may be comprised of prominent tones that are clearly audible on the ground. Tonal noise can often increase the likelihood of annoyance and/or complaint over that compared to the A-weighted noise level.

A specific case is that of the Airbus A320 family where a safety device called the Fuel Over Pressure Protector (FOPP) (consisting of cavities on the underside of the wing) generates audible tones as much as 15 dB higher than that of adjacent frequencies during certain phases of flight. The FOPP tonal noise is most prominent during the intermediate approach phase, prior to deployment of flaps and landing gear.

Airbus has developed a FOPP air flow deflector that alters the flow of air over the FOPP cavity and prevents the tone from occurring. The air flow deflector has been incorporated into standard production since June 2014 and Airbus now offers the deflector for retrofitting to existing Airbus A320 family aircraft. Both British Airways and easyJet have committed to retrofit the device to their existing fleet and aim to complete this by the end of 2017. In January 2017 Gatwick Airport announced that four of the top five A320 operators at Gatwick have committed to retrofit their fleets by the end of 2017[18].

Measurements at Gatwick airport (**Figure 8**) have identified overall A-weighted noise reductions of up to 5 dB at 30 km from touchdown for aircraft fitted with the device. Measuring the benefits of the FOPP air flow deflector is complicated by the variation of inbound arrival tracks (due to vectoring) and the need for low background levels to measure aircraft noise at large distances from the airports.

Figure 8 Noise benefit of FOPP air flow deflector based on easyJet arrivals at Gatwick between Sept 2014 - Feb 2015



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[18] Gatwick Arrivals Review Progress Report, Gatwick Airport, January 2017. https://www.gatwickairport.com/globalassets/gatwick---arrivals-review---update-d1-web.pdf (accessed 19 June 2017).

Chapter 4

Monitoring arrivals noise to identify non-CDO and/or non-LP/LD approaches

Introduction

One of the Technical Working Group's tasks, as outlined in its Terms of Reference, was to review and assess the difficulties in monitoring arrival noise, especially prior to glide path intercept. The TWG was also asked to review to what extent noise monitoring can and cannot be used to identify non-CDO and/or non-LP/LD approaches.

The TWG agreed that a review of the 1999 DETR arrivals report could effectively cover this task, as it had previously considered a range of factors which can affect the practicability of routine approach noise monitoring and had also examined the feasibility of applying approach noise limits. This chapter provides a summary of the main factors considered.

Operational factors

The accepted best practice for aircraft on approach is for the glide path to be captured after the localiser, after which the aircraft is then considered to be 'established' on the ILS. Since effective noise monitoring requires that aircraft pass within a 60 degree cone overhead of the noise monitor[19], this cannot be achieved with a practicable number of noise monitors until aircraft are established on the ILS (as there are no published flight paths between the holds and the final approach). For example, **Figure 9** illustrates the number of noise monitors (up to eight, or possibly more) that would be required for effective monitoring of westerly arrivals *prior* to joining the localiser at Gatwick. To also monitor easterly arrivals to the west of the airport would require an equivalent number of additional monitors. At other airports where arrivals can join from both sides of the localiser (e.g. from the north or the south) then this would further double the required number of monitors. Therefore, effective noise monitoring of CDO performance prior to the capture of the glide path is not practical.

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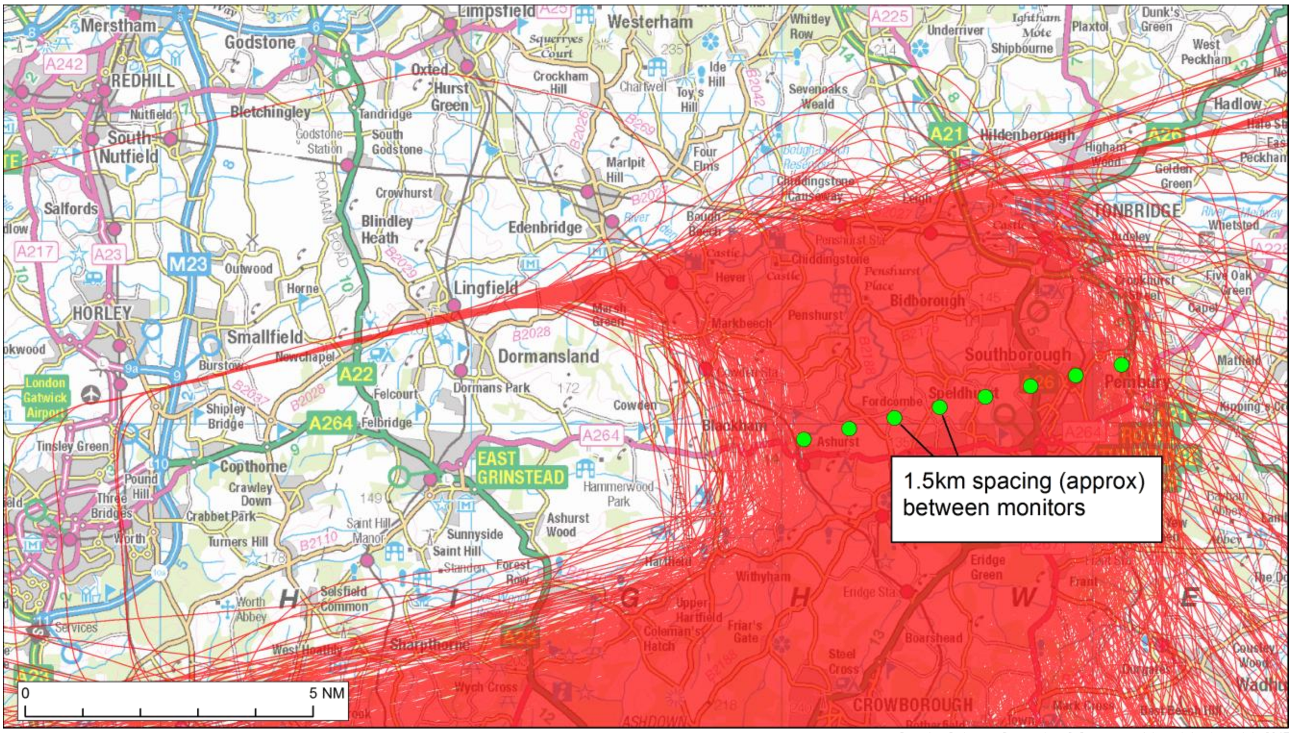
[19] Departure Noise Limits and Monitoring Arrangements at Heathrow, Gatwick and Stansted Airports, ERCD Report 0207, Civil Aviation Authority, April 2003

Figure 9 Example of a noise monitor array required for effective monitoring of arrivals prior to joining the localiser at Gatwick



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Routine approach noise monitoring can therefore only take place where the majority of aircraft are on the extended runway centreline, which typically occurs at around 10 NM or closer, depending on airport and runway direction. In fact, in recent years noise monitors have been located at such locations across all three airports in order to provide routine arrival noise data for ERCD's annual noise model validation studies[20].

An alternative option for monitoring arrivals prior to joining the localiser would be to deploy a smaller number of mobile noise monitors, which could be moved around according to a sampling plan. However, as noted in the 1999 DETR report, there could be major operational and practical difficulties associated with such a random form of noise monitoring when subsequently trying to compare measurements to a benchmark level or limit.

Once established on the ILS, aircraft are then not required to be in any configuration other than the final landing configuration at any point after passing 5 NM from the landing threshold. Since the aircraft configuration and thrust is closely defined on final approach between 0 and 5 NM, operators have little or no scope to apply lower noise procedures and in most cases the only practical option for mitigating noise is airline implementation of reduced landing flap procedures. For this reason it can be concluded that the region 0 to 5 NM is unsuitable for routine approach noise monitoring for the purposes of applying

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[20] Noise monitor positions at Heathrow, Gatwick and Stansted Airports, CAP 1149, Civil Aviation Authority, December 2016

noise limits. Monitoring in this region can however be used to capture and understand noise improvements over time. Between 5 and 6 NM there is also the possibility that a relatively large proportion of aircraft may initiate the lowering of the undercarriage (corresponding to heights between approximately 1,500 to 2,000 feet), see Appendix B. Therefore any sample of landings in that region could routinely include a mixture of quieter and noisier arrivals.

Monitor location

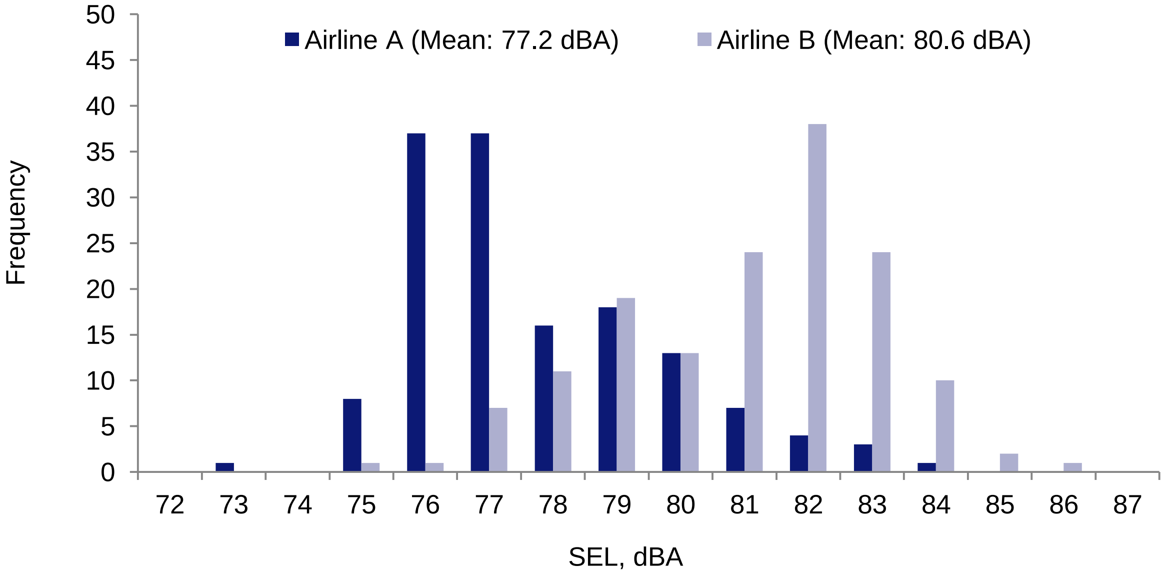
Due to the number of noise monitors required, effective noise monitoring of CDO performance prior to the capture of the glide path would not be practical. However, once aircraft have joined the final approach path, practical approach noise monitoring could be accomplished with a small and practical number of noise monitors, at distances between approximately 6 to 10 NM from landing threshold. Such monitoring would only measure the benefits of LP/LD.

When monitoring approach noise within 6 to 10 NM from landing threshold, there is limited scope for pilot discretion as the aircraft configuration will to a large extent be dictated by ATC speed control or weather, making it difficult to subsequently identify the cause(s) of a noisier arrival.

Type of noise monitoring: infringement or advisory

Measurements from the recent LP/LD monitoring exercise described in Appendix B indicate an average measured noise benefit resulting from the use of LP/LD for some aircraft types of 4 dB or more (at 7.5 NM). However, a notable amount of inherent data scatter was also observed, causing overlap in the noise level distributions of aircraft with and without landing gear deployed (e.g. **Figure 10**).

Figure 10 Distribution of 777-300ER arrival noise levels for two airlines



Therefore the monitoring of individual approaches may not necessarily reveal whether an aircraft operator had used the quietest possible technique or not, since it would need to be determined with sufficient confidence (e.g. through routine visual monitoring) which of the two distributions an individual noise event belongs to. In addition, for any aircraft deemed not to have used the quietest possible technique, to subsequently attribute any noise infringement to pilot action or ATC action would not be a straightforward task.

To avoid the weakness of a monitoring system based on individual (extreme) noise values, the possibility of a sample-based system was also considered, which could be approached in one of two ways: (1) by considering average values at a single noise monitor or (2) by considering the measurements of individual flights at a number of monitors, leading to the identification of 'consistently noisy' flights.

Either type of sample-based system would imply the application of 'differential' noise criteria appropriate to each aircraft type. The process for setting the values of any advisory levels (limits) would therefore need to be rigorously assessed. The question as to whether any individual noisy flight could be attributed to airline Standard Operating Procedures or ATC action would however still remain. Nonetheless, it may be possible to compare relative airline LP/LD performance on a type-by-type basis through long-term noise monitoring and incorporate results into existing airport environmental reporting, such as Heathrow's and Gatwick's *Fly Quiet and Clean* programmes[21],[22].

Noting that approach noise monitoring could yield useful operational information at distances between approximately 6 to 10 NM from landing threshold, the CAA welcomes Heathrow's announcement that it has begun the installation of fifty new noise monitors to help gain a better understanding of the impacts of noise in local areas[23]. For example, **Figure 11** shows Heathrow noise measurement data collected at 7.5 NM from landing threshold. Airline A operates both the Boeing 767-300ER and the slightly larger Boeing 787-8. The 787-8 is on average 1 dB quieter than the 767-300ER at this location. In contrast, the average noise level for the same 787-8 type operated by Airline B is almost 5 dB noisier than Airline A, making it more than 3 dB noisier than the older generation 767-300ER as operated by the other airline.

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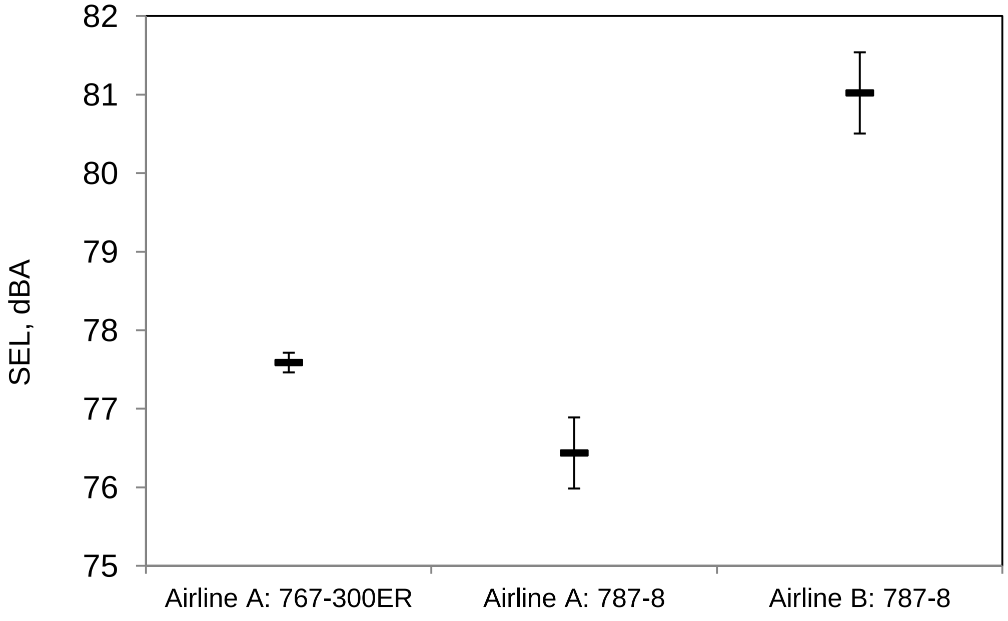
[21] http://www.heathrowflyquietandclean.com/ (accessed 19 June 2017)

[22] http://www.gatwickairport.com/business-community/aircraft-noise-airspace/what-were-doing/fly-quiet--clean/ (accessed 19 June 2017)

[23] 50 new noise monitors installed around Heathrow, HAL press release, 17 August, 2016. http://mediacentre.heathrow.com/pressrelease/details/81/Corporate-operational-24/7148 (accessed 19 June 2017).

Figure 11 Heathrow arrival noise measurements at 7.5 NM from landing threshold, summer 2014 (with 95% confidence intervals shown)



Chapter 5

Conclusions

The study summarises the operational factors that can affect noise from arriving aircraft and reviews the extent to which noise monitoring can be used to identify non-CDO and non-LP/LD approaches. Other environmental impacts were outside the scope of the study and so any interdependencies or trade-offs have not been considered.

The optimal approach trajectory giving minimum noise is a Continuous Descent Operation (CDO). When a CDO procedure is flown the aircraft stays higher for longer (increasing the distance between the noise source and the ground), descending continuously from the level of the bottom of the stack (or higher if possible) and avoiding any level segments of flight prior to intercepting the 3 degree glide path. A continuous descent also requires significantly less engine thrust than required for level flight, reducing the amount of noise emitted at source.

Low power/low drag (LP/LD) is the collective term used for describing the lowest noise configuration for a given speed and/or altitude during the approach. Selecting more flap than is required for a given speed will typically lead to more airframe noise, higher engine power to overcome the greater drag (for a given descent angle and speed) and thus higher noise. Deployment of landing gear (wheels down) increases aircraft drag, requiring higher engine power to be used, again emitting more noise. Landing gear also generates air turbulence causing additional noise. Noise measurements indicate that early landing gear deployment can increase noise by 3 to 5 dB in the region 5 to 10 NM from landing threshold, which can be greater than the difference in noise between the latest generation of aircraft and the generation they replaced.

Due to the number of noise monitors required, effective noise monitoring of CDO performance prior to the capture of the glide path would not be practical. However, once aircraft have joined the final approach path, practical approach noise monitoring could be accomplished with a small and practical number of noise monitors, at distances between approximately 6 to 10 NM from landing threshold. Such monitoring would only measure the benefits of LP/LD.

When monitoring approach noise within 6 to 10 NM from landing threshold, there is limited scope for pilot discretion as the aircraft configuration will to a large extent be dictated by ATC speed control, making it difficult to subsequently attribute any noisier arrival to pilot, aircraft system or ATC action. A limit-based noise monitoring system, similar to that for departures, would therefore not be feasible. Instead it may be possible to compare relative airline LP/LD performance on a type-by-type basis through long-term noise monitoring and incorporate results into existing airport environmental reporting.

APPENDIX A

Glossary

ATC	Air Traffic Control
dB	Decibel units describing sound level or changes of sound level.
CDO	Continuous Descent Operation
ERCD	Environmental Research and Consultancy Department of the CAA
Flight Level	The altitude of an aircraft given in multiples of 100 feet, referenced to International Standard Atmosphere pressure at mean sea level,
Glide path	The vertical path of the aircraft once established on the ILS. Part of the ILS that provides vertical guidance to landing aircraft. The international standard glide path angle is 3 degrees. However, it may vary at some airports due to obstacles.
ILS	Instrument Landing System. Ground-based radio transmitters that provide precision lateral and vertical guidance to an aircraft approaching and landing on a runway.
Localiser	Part of the ILS that provides horizontal guidance to landing aircraft.
LP/LD	Low Power/Low Drag
NATS	The UK Air Navigation Service Provider that provides approach control to the London airports.
NM	Nautical Miles, equivalent to 1,852 metres
SEL	Sound Exposure Level. A single event noise level that accounts for both the level and duration of an aircraft noise event.
Threshold	The beginning of that portion of the runway usable for landing.

APPENDIX B

Observations of (LP/LD) procedures at Heathrow and Gatwick

The use of Low Power/Low Drag (LP/LD) procedures can produce substantial noise benefits under approach flight paths relative to traditional approach procedures. During summer 2013 and summer 2014, ERCD repeated part of a 1978 CAA study[1] on LP/LD that included ground-based visual observations of approaches into Heathrow Airport.

The aim of the new CAA study was to compile statistics at Heathrow and Gatwick on the distance to landing for 'gear down', with deployment of landing gear being used as a proxy for an aircraft not being in an LP/LD configuration. Observations were not conducted at Stansted due to the lower overall number of daily movements and more limited mix of carriers compared to the other two airports. At Heathrow[24], additional observations were also undertaken by the CAA during the early morning period (0530-0700) in order to collect data for a variety of different carriers and aircraft types, see below.

Airport	Date of observations
Heathrow (daytime)	12 and 13 August 2013, 10 and 11 June 2014
Heathrow (early morning)	5 and 22 August 2014
Gatwick (daytime)	5 August 2014

Observations at Heathrow were initially undertaken simultaneously at three locations close to the extended centreline of runway 27R (the northern runway) at approximately 10.0, 7.5 and 5.5 NM from threshold – see **Figure B1**. The close-in location at Kew Green was determined by the optimal[25] point of wheels down (5 NM/1,500 feet) and the far-out point in Battersea corresponded to the point where aircraft approximately join the glide path at 3,000 feet.

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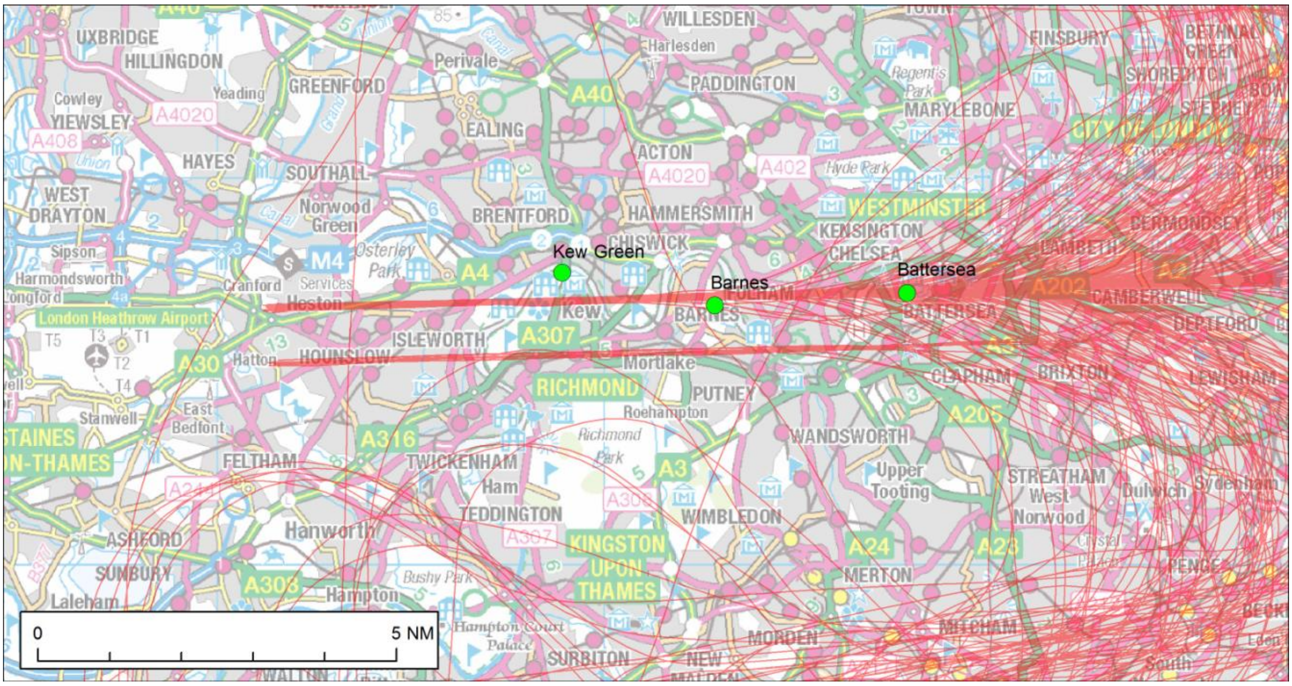
[24] A subsequent study was carried out by Heathrow Airport in 2015. See *Heathrow's Blueprint for noise reduction*, Heathrow Airport Limited, August 2016. http://www.heathrow.com/noise/making-heathrow-quieter/our-noise-strategy/blueprint-for-noise-reduction (accessed 19 June 2017)

[25] ICAO Doc. 8168 (PANS-OPS) Volume I describes operational procedures recommended for the guidance of flight operations personnel and flight crew. Section 7, Chapter 3.4.1 a) states that "the aeroplane shall not be required to be in any configuration other than the final landing configuration at any point after passing the outer marker or 5 NM from the threshold of the runway of intended landing, whichever is earlier"

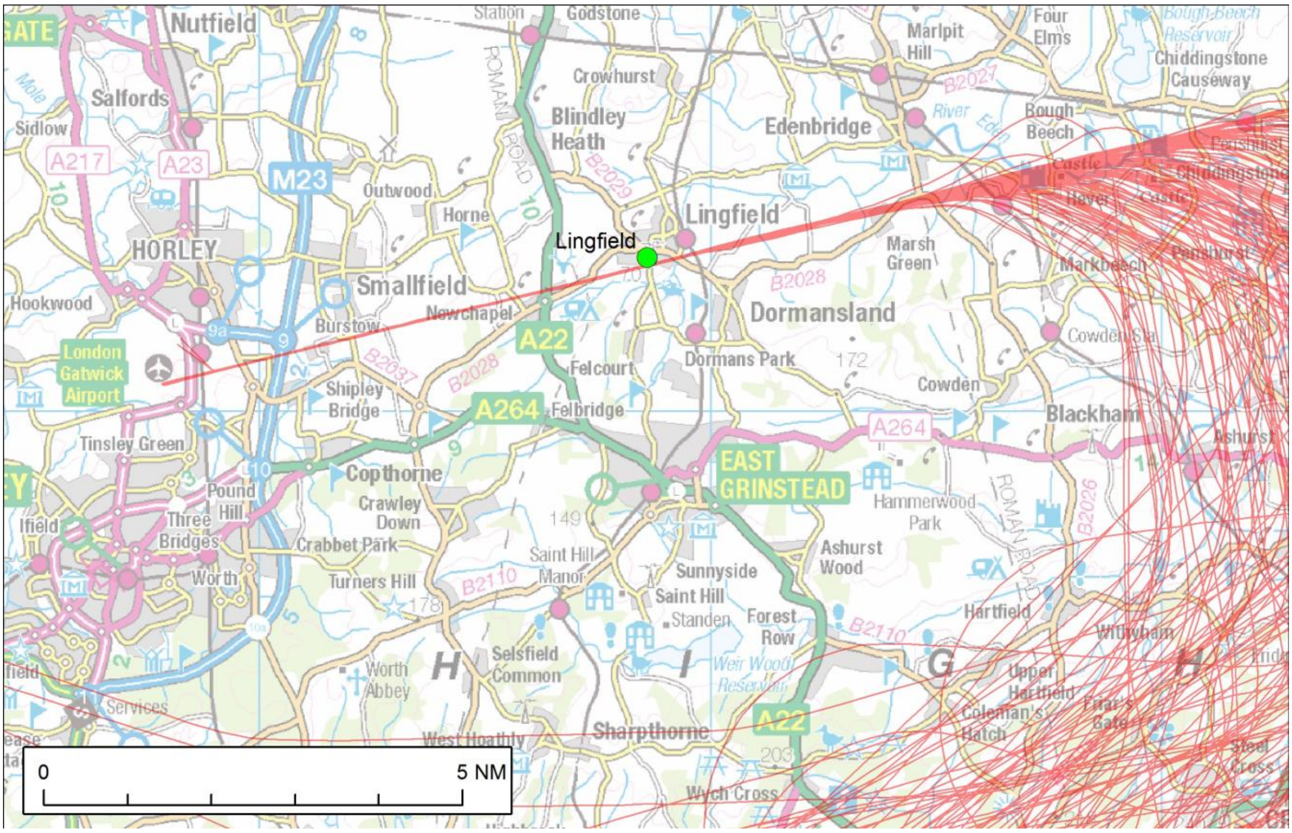
Figure B1 Locations used for observations of westerly approaches into Heathrow



The intermediate location in Barnes was selected because a mobile airport noise monitor had already been deployed at that location for the summer 2013 period, and it provided a good vantage point between the other two sites. This allowed observations of landing configuration over the Barnes location to be correlated with noise measurements. Each observation point provided a clear line-of-sight such that the approach path to runway 27L (the southern runway) could also be observed by ERCD staff.

After initial observations were made on 12 and 13 August 2013, the Barnes location was found to provide a clear line-of-sight from approximately 12 to 4 NM to threshold to the approach paths on both westerly runways. Therefore on subsequent days at Heathrow observations were made from the Barnes site only. At Gatwick, observations of daytime westerly arrivals were undertaken in Lingfield (6.1 NM from threshold) on 5 August 2014, see **Figure B2**. Like the Barnes site at Heathrow, the Lingfield location provided a clear line-of-sight to the Gatwick approach path from approximately 12 to 4 NM to threshold.

Figure B2 Location used for observations of westerly approaches into Gatwick

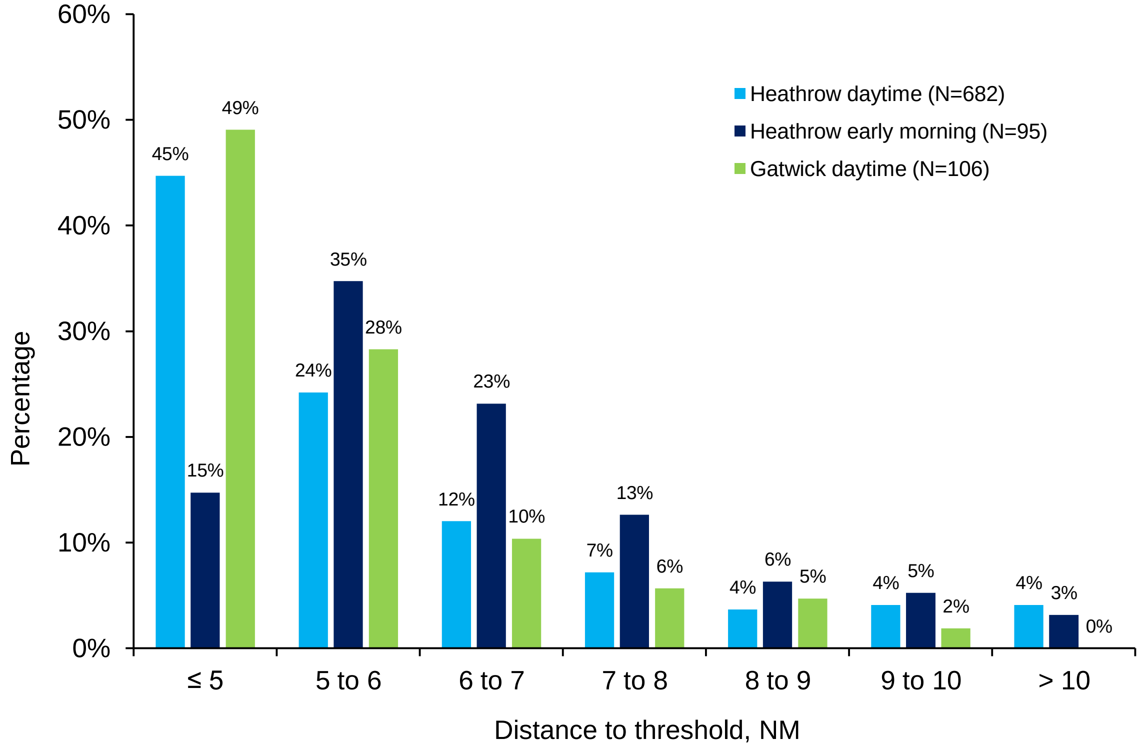


At each location, a note was taken of the exact time (using clocks synchronised to UTC) each aircraft first came into view and whether or not the landing gear had already been lowered. Arrivals that were still in a clean configuration were tracked using binoculars for as long as possible at each site and a note made of the time that deployment of the landing gear was initiated and deemed to be complete. In many cases aircraft were still in a clean configuration after passing out of final view, corresponding to a distance of approximately 4 NM. In total 777 arrivals were monitored at Heathrow (95 of which occurring during the early morning period) and 106 arrivals were monitored at Gatwick.

The written notes were subsequently cross-referenced to ATC logs to confirm aircraft type and airline operator. The distance to threshold when deployment of the landing gear was initiated for each arrival was then obtained from an analysis of the time-stamped radar data from the airports' Noise and Track Keeping systems. Even with a timing error of a few seconds, the error in the calculated distance to threshold value for any single arrival is expected to be no greater than ±0.25 NM.

Figure B3 compares the observed distances to threshold for deployment of landing gear at each airport, with results grouped into 1 NM bands. Due to the large difference in fleet mix between the daytime and early morning periods at Heathrow, results are shown separately for each time period. At Heathrow approximately 82 percent of the flights monitored during the daytime were operated by UK and mainland European carriers, which were mainly comprised of narrow body short-haul aircraft. However, during the early morning monitoring period the proportion of UK carriers was less than 50 percent (with no European carriers landing during that time).

Figure B3 Distance to threshold for observed deployment of landing gear



The results for daytime arrivals appear broadly comparable at both airports. For example, less than one third of daytime arrivals at Heathrow and Gatwick were observed deploying landing gear further out than 6 NM to threshold. The distribution for the early morning arrivals at Heathrow on the other hand shows a marked difference in shape compared to the daytime results, with approximately half of all arrivals deploying landing gear before reaching the same distance to threshold.

Tables B1 and B2 summarise the number of observed arrivals at Heathrow and Gatwick, grouped by region of airline registration. Approximately 12 percent of all Heathrow flights were observed with landing gear down at a distance to threshold greater than 8 NM, which corresponds to a height of approximately 2,500 feet for an aircraft on a 3 degree approach. Though small in absolute numbers, the results indicate a relatively large proportion of these flights were operated by Middle-Eastern and Asian carriers. Carriers from these regions tend to operate many of the newest (and potentially quieter) aircraft types, including the Boeing 787 and Airbus A380.

At Gatwick approximately 7 percent of flights were observed with gear down before reaching 8 NM, although it should be noted that the sample size is smaller than for Heathrow. Of the 82 arrivals at Gatwick that were operated by UK carriers (which were comprised mainly of narrow body short-haul aircraft) only one flight was observed with gear down beyond 8 NM. Sample sizes for carriers from other regions are too small to draw any meaningful conclusions.

Table B1 Count and percentage of Heathrow arrivals by region of airline registration

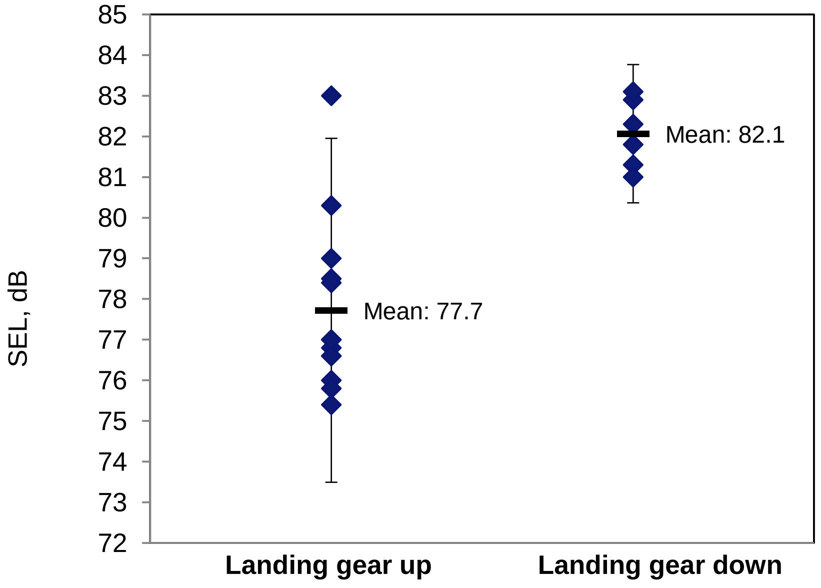
Region	Landing gear deployed closer in than 8 NM	Landing gear deployed further out than 8 NM
Africa	7 (54%)	6 (46%)
Asia	22 (56%)	17 (44%)
Australasia	4 (80%)	1 (20%)
Europe (non UK)	156 (91%)	15 (9%)
Middle East	18 (56%)	14 (44%)
North America	61 (79%)	16 (21%)
South America	1 (33%)	2 (67%)
United Kingdom	413 (95%)	24 (5%)
Total	682 (88%)	95 (12%)

Table B2 Count and percentage of Gatwick arrivals by region of airline registration

Region	Landing gear deployed closer in than 8 NM	Landing gear deployed further out than 8 NM
Europe (non UK)	16 (73%)	6 (27%)
Middle East	1 (100%)	0 (0%)
North America	1 (100%)	0 (0%)
United Kingdom	81 (99%)	1 (1%)
Total	99 (93%)	7 (7%)

As mentioned above, a mobile airport noise monitor was deployed at the Barnes observation location in summer 2013. During the series of attended observations made on 12 and 13 August 2013, the Boeing 777-300ER had the largest individual sample of ‘gear down’ measurements when passing directly over the noise monitor. **Figure B4** presents the noise measurements for the 777-300ER grouped according to the observed aircraft configuration (with error bars indicating ±2 standard deviations). The results show an average measured noise benefit resulting from the use of LP/LD of more than 4 dB for this particular type. However, as **Figure B4** also illustrates, the large inherent scatter of arrival noise levels would make it difficult to distinguish non-adherence of LP/LD through noise monitoring alone.

Figure B4 Boeing 777-300ER arrival noise levels (7.5 NM from threshold)



Whilst **Figure B4** presents data acquired over the two days of *attended* observations (on 12 and 13 August 2013), **Figure B5** presents the distribution of noise measurements for all 777-300ER arrivals over the entire summer 2013 period. The data covers 20 different airline operators of the same aircraft type. Two separate peaks approximately 5 dB apart are visible in the distribution, which are likely to be caused by varying LP/LD performance as a consequence of different Standard Operating Procedures (SOPs) across the various airlines. This is further highlighted in **Figure B6**, which presents a subset of the data for two specific 777-300ER operators, both of which are known to have different SOPs on approach.

Figure B5 Distribution of 777-300ER arrival noise levels at 7.5 NM from threshold (all airlines)

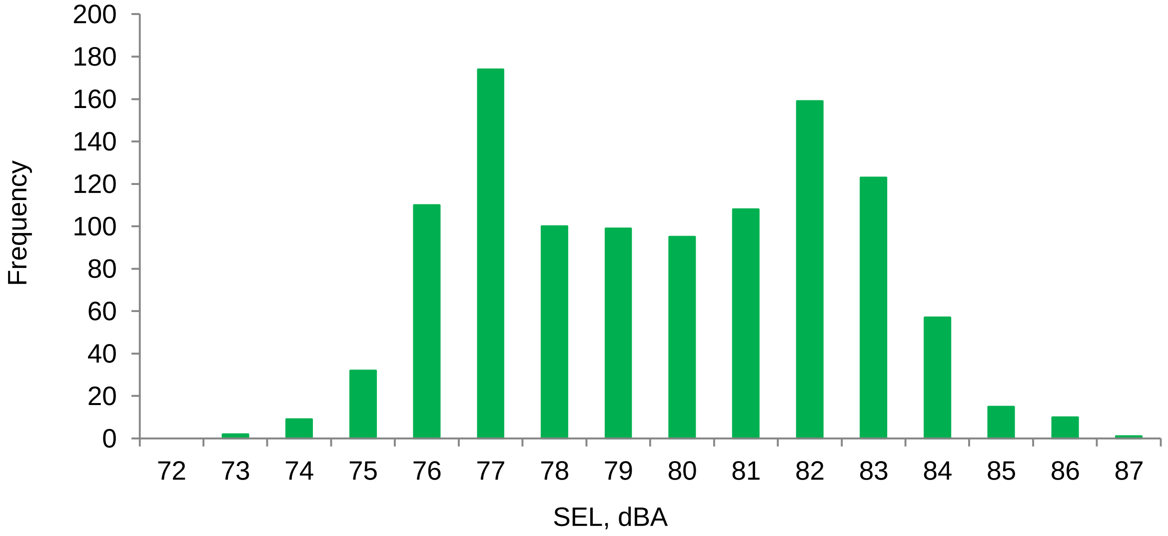
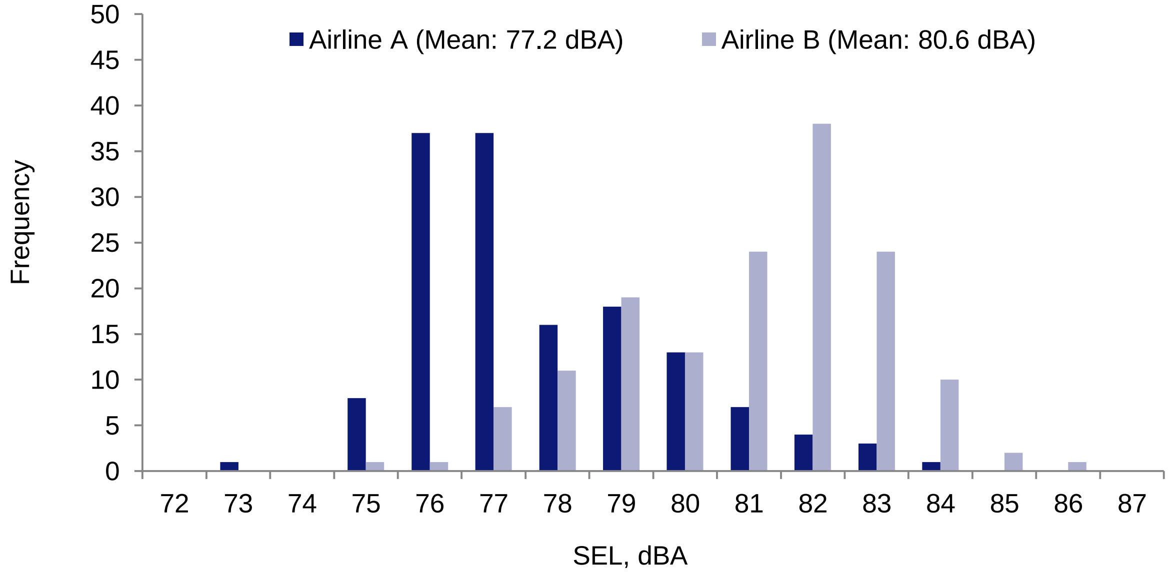


Figure B6 Distribution of 777-300ER arrival noise levels for two airlines



ICAO Doc. 8168 (PANS-OPS) Volume I requires that in instrument meteorological conditions (IMC), all flights shall be stabilised by no lower than 1,000 feet above threshold. It also requires that an aircraft not be required to be in any configuration other than the final landing configuration at 5 NM from the threshold of the runway. In this instance, airline A’s SOP requires a stabilised approach to be achieved by 1,000 feet (corresponding to approximately 3 NM from threshold) whereas for airline B the minimum height for a stabilised approach is 1,500 feet (5 NM). In practice this would require flight crews to deploy the landing gear well in advance of these heights in order to complete the full landing checklist.

Thus, airline B would be expected to deploy landing gear around 500 feet earlier than airline A on a routine basis. It is therefore likely that the operator differences shown in **Figure B6** can largely be explained by the different configuration of the landing gear at that location. Other factors, such as air speed, landing weight and engine power were assessed and found to have no influence on measured noise levels.