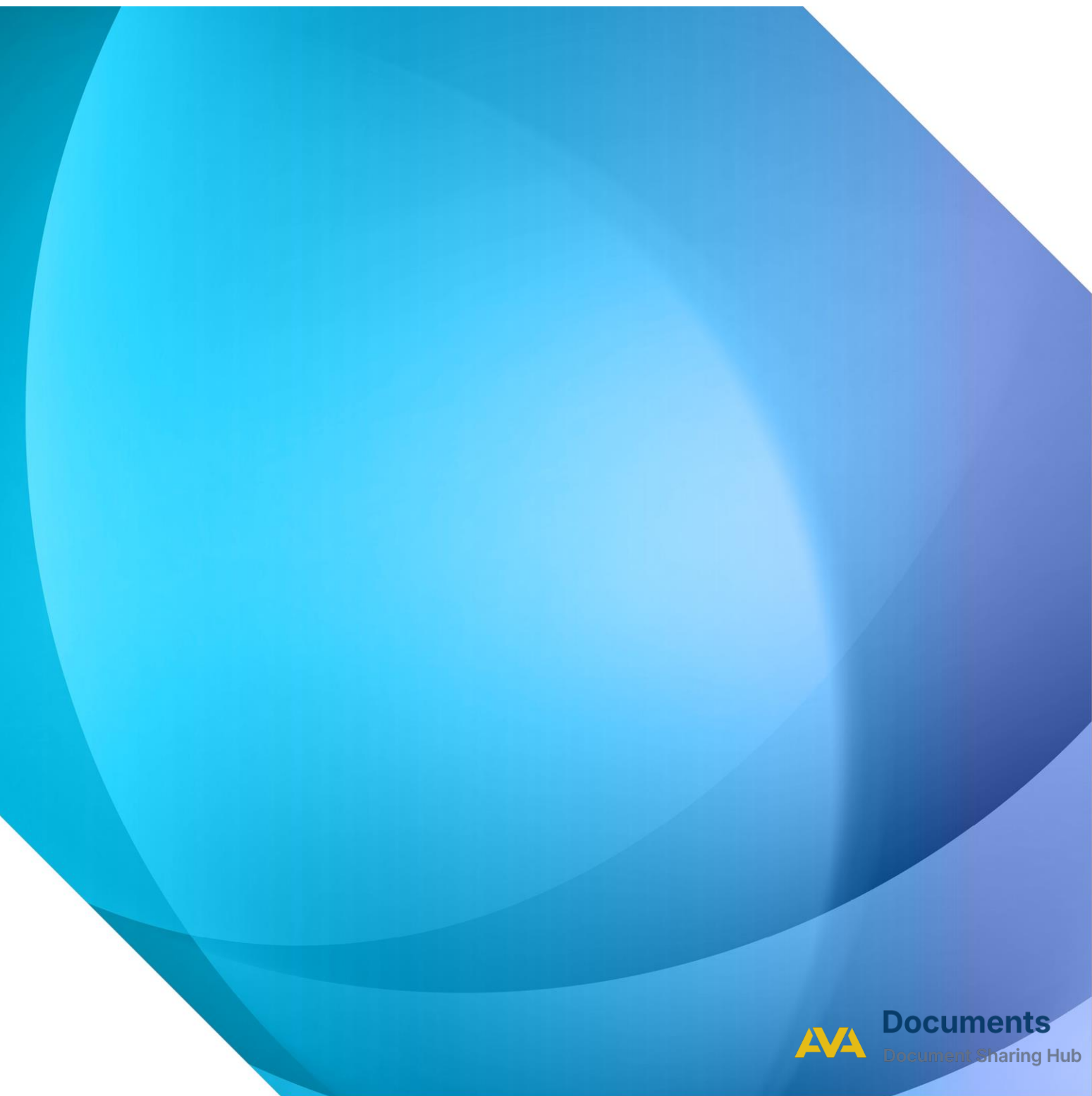


A Low Noise Arrival Metric

CAP 2302



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Executive Summary

A major government review of noise from arriving aircraft, published in 1999, identified that the use of Continuous Descent Operations (CDO) was the primary means of reducing noise experienced on the ground beneath arriving aircraft. The report recommended the development of a new code of practice to promote the use of CDOs and to monitor compliance. This was subsequently published in 2002 and a second edition published in 2006.

Since the early 2000s, the designated London airports have regularly reported operational compliance with the CDO definition on a monthly and annual basis. Under the current CDO definition, the designated London airports have reached and maintained high compliance rates.

In 2017, preliminary research performed by CAA's Environmental Research and Consultancy Department (ERCD) identified that the existing CDO definition was not sufficiently sensitive to provide an effective noise measure. The current CDO definition focuses on the avoidance of prolonged level flight. This presents the following issues:

- Permittance of shallow angle approaches which are classified as CDO, and which could be noisier at certain points on the approach compared to a traditional non-CDO approach.
- On newer aerodynamically efficient low drag aircraft (e.g. A350 and B787-8) it may not be possible to deliver optimal low noise arrivals within the existing operational constraints and the current CDO definition. These aircraft types may require shallower descent segments or level flight during the initial approach (at higher altitude) in order to reduce speed on approach and remain in a Low Power/Low Drag (LP/LD) configuration whilst complying with CDO requirements.

The study analysed approach performance for four aircraft:

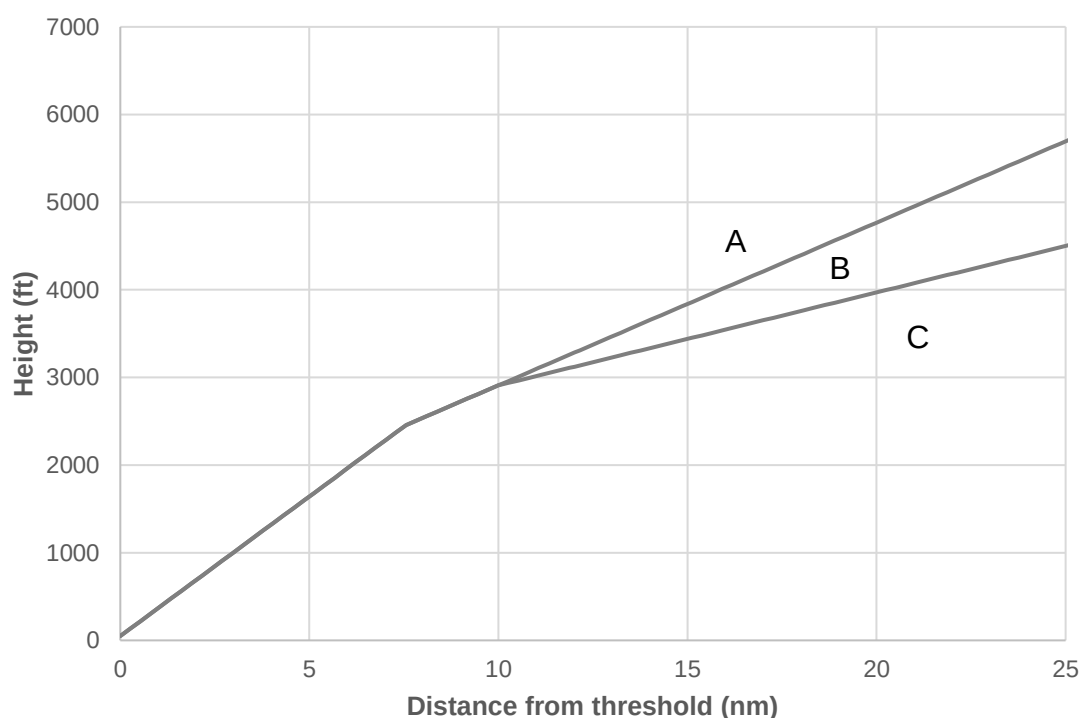
- Airbus A320
- Airbus A380
- Boeing 787-8
- Bombardier Dash 8

Of the aircraft studied, it was found that the Boeing 787-8 is the most difficult aircraft to slow down whilst descending because it has the lowest drag. As a result, further analysis was only undertaken for the Boeing 787-8 and is presented in the report. The analysis found that:

- For modern aircraft types and current operational speed constraints, optimum noise is achieved for intermediate approach angles around 2.5 degrees

- To achieve a 3 degree intermediate angle requires additional drag, which generates additional airframe noise and additional thrust when flying at constant speed, increasing noise when compared with intermediate approach angles of around 2.5 degrees
- Shallow angle CDO profiles significantly increase noise compared with the optimum intermediate approach profile
- Short level segments at heights of around 6,000 ft, when used to decelerate an aircraft at idle power, result in little noise increase relative to the optimum profile, whereas level segments flown at constant speed close to the Instrument Landing System (ILS) intercept increase noise for the entire intermediate approach phase (10-20 NM from touchdown)
- Shallow angle CDO profiles are noisier than non-CDO approaches with steeper intermediate approach angles

These insights led to the development of height-based criteria for a low noise arrival metric that would incentivise increased initial/intermediate descent angles, but not to the extent that would necessitate any changes in speed control or aircraft configuration. To better incentivise low noise arrival performance, two height boundary conditions are proposed as illustrated below, creating three height zones or low noise categories.



Quantitatively, the upper and lower boundaries are defined as:

Upper boundary:

- A line starting at 50 ft height above the landing runway threshold, extending out to 7.5 nm at an angle of 3 degrees
- A line at an angle of 1.75 degrees between 7.5 NM and 10 NM

- A line at an angle of 1.75 degrees between 10 NM and 6,000 ft altitude above mean sea level (AMSL)

Lower boundary:

- A line starting at 50 ft height above the landing runway threshold, extending out to 7.5 nm at an angle of 3 degrees
- A line at an angle of 1.75 degrees between 7.5 NM and 10 NM
- A line at an angle of 1.0 degrees between 10 NM and 6,000 ft above mean seal level (AMSL)

Testing indicates that the criteria would rate 45-50% of arrivals in the optimum category, with around 15-20% of arrivals in the second category and 35-40% in the lowest category.

The following recommendations are made:

- Monitoring systems should be developed to implement the proposed low noise arrival metric definitions, and be appropriately validated.
- Concurrent monitoring of CDO and low noise metric performance should be undertaken. The identification of proportions of flights classified as both CDO and non-CDO, within the three low noise arrival categories should be assessed and reviewed with a view as to whether the existing CDO criteria should be incorporated into the proposed low noise arrival metric definitions or remain separate.
- Recognising the current inability to monitor LP/LD performance, encourage development of automated systems to monitor landing gear deployment.

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Chapter 1

Introduction

From as early as 1978, CAA studies¹ have identified best practice measures to reduce arrival noise in the form of Continuous Descent Operations (CDO), which aim to keep aircraft higher for longer during their approach, and Low Power/Low Drag (LP/LD) procedures, which maintain a more aerodynamic aircraft configuration for longer. A CDO is commonly referred to as a Continuous Descent Approach (CDA) in the UK, which is typically measured from an altitude of 6,000 ft. However, the term CDO is used throughout this report in keeping with international usage.

A major government review of noise from arriving aircraft, published in 1999², identified that the use of CDO was the primary means of reducing noise experienced on the ground beneath arriving aircraft. The report recommended the development of a new code of practice to promote the use of CDOs and to monitor compliance. This was subsequently published in 2002³ and a second edition published in 2006⁴.

Since the early 2000s, the designated London airports have regularly reported operational compliance with the CDO definition on a monthly and annual basis. Under the current CDO definition, the designated London airports have reached and maintained high compliance rates. However, in 2017, preliminary research performed by the CAA's Environmental Research and Consultancy Department (ERCD) identified that the existing CDO definition was not sufficiently sensitive to provide an effective noise measure.

The current CDO definition focuses on the avoidance of prolonged level flight. This presents the following issues:

- Permittance of shallow angle approaches which are classified as CDO and which could be noisier at certain points of the approach compared to a traditional non-CDO approach.

¹ CAA Paper 78002, A Technical Evaluation of Initial Trials of Quieter Approach Procedures at London (Heathrow) Airport Summary Report, Civil Aviation Authority, February 1978.

² Noise from Arriving Aircraft: Final Report of the ANMAC technical working group, Department of the Environment, Transport and the Regions (DETR), December 1999.

³ Noise from Arriving Aircraft: An Industry Code of Practice, Department for Transport, Local Government and the Regions (DfT), et al., February 2002.

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

- On newer aerodynamically efficient low drag aircraft (i.e. A350 and B787-8) it may not be possible to deliver optimal low noise arrivals within the existing operational constraints and the current CDO definition. These aircraft types may require shallower descent segments or level flight during the initial approach (at higher altitude) in order to reduce speed on approach and remain in a LP/LD configuration whilst complying with CDO requirements.

The high compliance percentage associated with the current CDO definition means that there is no further incentive or reward to further reduce noise from arriving aircraft. An alternative, low noise arrival definition would incentivise additional reductions in approach noise and support the development of more advanced navigation arrival procedures, whilst also adapting to allow for the optimum low noise arrivals on new aircraft types. An alternative solution would potentially deliver further improvements in noise reduction, enable environmental benefits and help aviation to grow sustainably.

In 2017, a national cross-industry project was established to develop a new low noise arrival metric which would supplement the current CDO definition and provide a new target to reduce arrival noise in the near term on both the current in-service fleet and new aircraft types. A new low noise arrival metric would take into account the latest understanding on aircraft noise modelling, reflecting the increasing importance of airframe noise as jet noise is reduced, accommodate LP/LD operations, and focus on optimising approaches within the main area of concern for approach noise; between 7,000 ft and 1,800 ft above aerodrome level.

In the long-term, the outcomes of this study will inform the design of future Performance Based Navigation (PBN) arrival procedures to minimise noise impacts.

This study was sponsored by the Future Airspace Strategy (FAS) and overseen by Sustainable Aviation (SA). CAA ERCD were approached to undertake the technical aspects of the study, whilst NATS tested the criteria using historic radar data.

The report is structured as follows:

- Chapter 2 presents the background to the study
- Chapter 3 presents the study methodology
- Chapter 4 presents the results of the arrival performance and noise analysis
- Chapter 5 presents the proposed low noise arrival metric
- Chapter 6 presents the conclusions and recommendations

Chapter 2

Background

Continuous Descent Operation

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

- 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.

For a typical non-CDO 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 ft) to descend to an altitude of typically 3,000 ft and decelerate from the holding speed of 220 kt down to 180 kt. 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, and the aircraft noise source would be closer to the ground than would have been the case for a CDO approach.

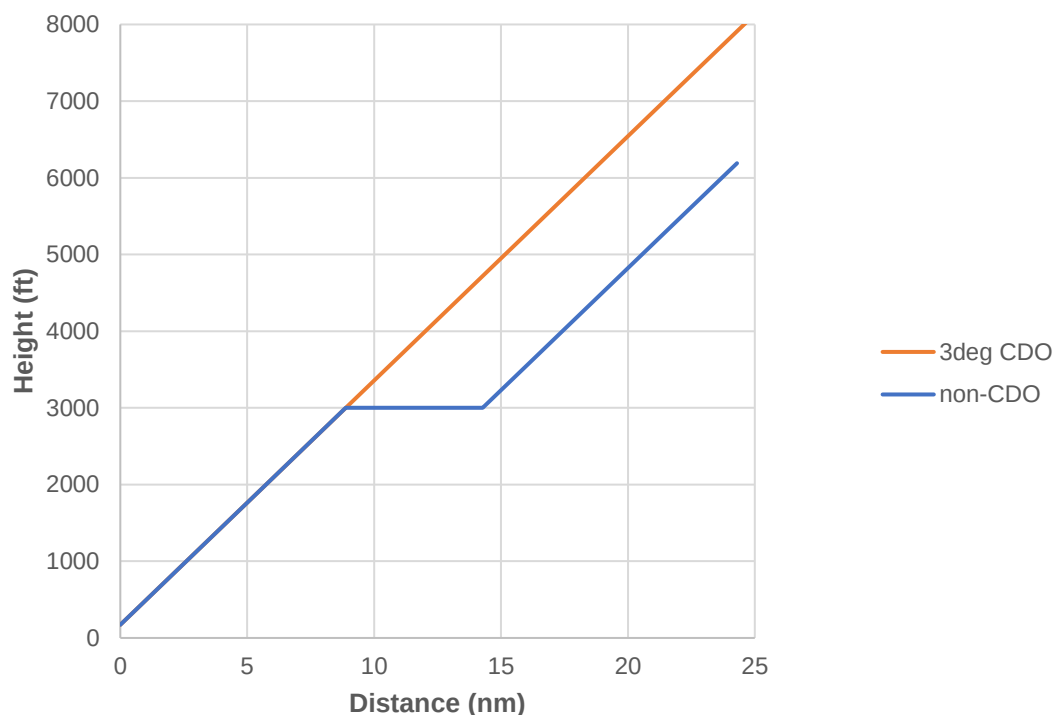
In contrast to a non-CDO approach, a CDO approach is flown when the aircraft stays higher for longer, descending continuously from the level of the bottom of the stack (or higher if possible) and avoiding any extended level segments of flight prior to intercepting the 3 degree glide path. A continuous descent requires significantly less engine thrust than required for level flight and increases the distance between the aircraft and the ground, allowing the emitted noise to attenuate further before reaching ground level. CDO descent rates vary, such that an optimal CDO would require low or idle engine thrust, whereas the existing CDO definition allows aircraft to achieve a CDO by applying a reduced rate of descent, requiring higher thrust and with the aircraft noise source closer to the ground.

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 between 3,000 and 6,000 ft. Compared to an optimal CDO, this results in noise increases of up to 2.5 to 5 dB, varying over distances of 10 to 20 NM from touchdown. Further detail can be found in CAA CAP 1554⁵.

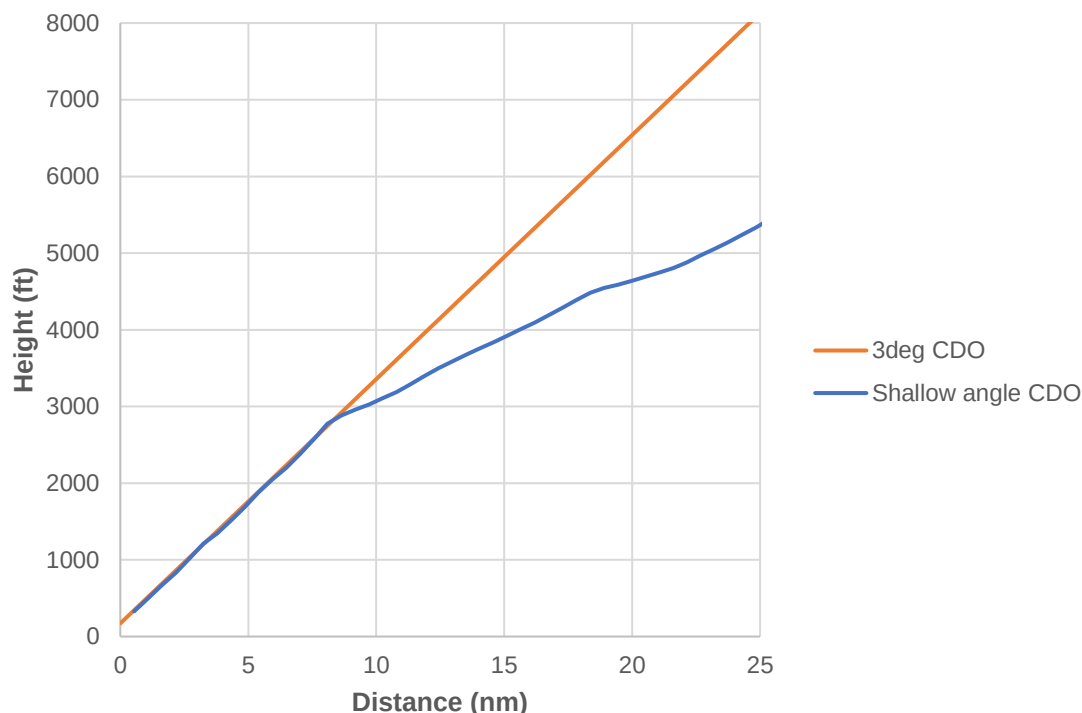
⁵ [CAA CAP 1554 Review of Arrival Noise Controls, Civil Aviation Authority, July 2017.](#)

A CDO approach is flown when an aircraft stays higher for longer, descending continuously, and avoiding any extended level segments of flight prior to intercepting the 3 degree glide path. The angle of descent affects noise on the ground. **Figure 1** illustrates target CDO and typical non-CDO arrivals respectively.

Figure 1. Optimum CDO arrival profile vs a non-CDO profile



In today's operation, a CDO angle of descent can vary and as such, arrivals are categorised as CDO compliant but may not necessarily be low noise arrivals. **Figure 2** below illustrates a CDO compliant aircraft with a shallow angle of descent. The aircraft in this example would have a larger noise impact on the ground compared to the target CDO.

Figure 2. Example of a shallow angle CDO approach

Low Power/Low Drag (LP/LD)

For most arriving aircraft, pilots are instructed by ATC to fly at set speeds. This is necessary in order to achieve a uniform flow of arriving aircraft and maintain a high landing rate. As an aircraft reduces speed during the initial and intermediate approach phases to comply with ATC instructions, flaps are deployed to allow the aircraft to fly slower and prepare 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.

LP/LD is the collective term used to describe the aircraft configuration that creates the lowest noise for a given speed and/or altitude during an approach. Selecting more flap than is required for a given speed will typically lead to more airframe noise, higher engine power needed to balance the greater drag, and thus increased noise. The 1999 ANMAC review⁶ considered only flap angle during the final approach phase and concluded that LP/LD offered no more than 1 dB noise reduction.

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

In contrast, deployment of the landing gear significantly increases airframe noise and aircraft drag, and to maintain the flight path requires increases in engine thrust. The combined effect may be as much as 5 dB. Further detail can be found in CAA CAP 1554⁷.

Although aircraft flying a CDO will typically be operating in a LP/LD configuration, there is no formal definition of LP/LD. At present, monitoring of all aspects of LP/LD is only possible through access to Flight Data Recorder (FDR) information. However, the largest component, landing gear, can be identified visually albeit using resource intensive visual methods.

Problem Statement

In 2017, preliminary research performed by CAA ERCD identified that the existing CDO definition was not sufficiently sensitive to provide an effective noise measure. The current CDO definition focuses on the avoidance of prolonged level flight. This presents the following issues:

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⁷ CAP 1554 Review of Arrival Noise Controls, Civil Aviation Authority, July 2017.

Figure 3 shows variation in CDO and non-CDO approach profiles. As long as no level segment longer than 2.5 NM is performed in the hatched area, any path will be compliant with the UK CDO definition. However, an approach profile with a level segment just exceeding 2.5 NM in length, and therefore not CDO-compliant but occurring at higher altitude than a shallow angle CDO, is likely to be quieter overall.